ALBERTA RENEWABLE ENERGY TEST SITE
EVALUATION OF
WIND & SOLAR PUMPING SYSTEMS
1993 TEST SEASON FINAL REPORT

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1993 TEST SEASON FINAL REPORT

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EXECUTIVE SUMMARY

The Alberta Renewable Energy Test Site (ARETS) is the successor of the Lethbridge Wind Research Test Site which was established in 1982 for the purpose of evaluating and demonstrating the use of water pumping wind turbines for local agricultural applications. Its operation has since been extended to include the evaluation and demonstration of all renewable energy technologies as applied to agricultural applications in both domestic and export markets. In 1993, the focus was on the use of photovoltaic panels and wind turbines for small scale water pumping applications (cattle watering, land reclamation) and for water quality applications (aeration).

The Alberta Renewable Energy Test Site is located in Pincher Creek, Alberta. It is funded jointly by Natural Resources Canada (Alternative Energy Division), Alberta Energy and Alberta Agriculture. The contracting authority is the Lethbridge Community College, while the scientific authority is the Alberta Farm Machinery Research Centre (also located in Lethbridge, Alberta).

This report presents the results of the tests performed during the 1993 test season. Sixteen performance tests were performed on ten water pumping systems (four solar systems [eight configurations], six wind systems [eight configurations]). Two additional wind systems were installed on the site during 1993 for initial assessment and demonstration - full testing on these systems is planned for the 1994 test season.

The most significant advance in the test site's operation was the initiation of an aeration test procedure. Of the sixteen tests, six were performed on "aeration only" pumping systems and an additional two were performed on hybrid pumping/aeration systems. The test results during 1993 indicate continued improvements in reliability of Canadian manufactured renewable energy systems. The industry has overcome many of its initial reliability problems and is now concentrating on improving their product line and expanding into new markets (such as aeration). This report highlights the technical advances achieved by the manufacturers of renewable energy pumping systems.

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1.0 INTRODUCTION

The Alberta Renewable Energy Test Site (ARETS) is the successor to the Lethbridge Wind Research Test Site which was created in 1982 by Alberta Agriculture as a program of testing and demonstrating commercially available wind turbines for agricultural water pumping applications. In 1987, the scope of the project was expanded to include photovoltaic pumping systems to reflect the growing competitiveness that these systems had attained. In 1991 construction of the Alberta Renewable Energy Test Site at Pincher Creek, Alberta was initiated. Full operation of ARETS began in 1992. The three main objectives of the test site have been to:

1) evaluate the potential for wind turbines and solar systems to efficiently pump water for agricultural and export uses.
2) monitor, demonstrate and evaluate various types of wind and solar pumping equipment developed, manufactured or distributed in Alberta and Canada.
3) maintain a Canadian focal point for expertise in the design, evaluation and application of wind and solar water pumping systems and related technology.

The Alberta Renewable Energy Test Site is located immediately northeast of the town of Pincher Creek, Alberta, Canada. Presently, it is managed and operated jointly by Alberta Agriculture (Lethbridge), the Lethbridge Community College and DRB Engineering Consultants Ltd. (Calgary, Alberta). Funding for the Test Site has been provided by a number of agencies including: Alberta Heritage Trust Fund, Alberta/Canada Energy Resources Research Fund, Department of Energy, Mines and Resources Canada, Alberta Agriculture, the Farming For the Future Fund and TransAlta Utilities Corporation.

Mr. R. Atkins, Manager of the Alberta Farm Machinery Research Centre of Alberta

Agriculture is responsible for overall management of the Test Site. Mr. W. Evdokimoff, Associate Dean of Business & Industry Development at the Lethbridge Community College is responsible for administering and coordinating the funding contributions and their disbursement. Mr. D. Baker, President of DRB Engineering Consultants Ltd. is responsible for data collection and analysis and computer systems operation and maintenance. He is also responsible for site design and liaison with wind turbine and solar manufacturers. Temporary staff are hired as required to assist with the day-to-day operation and maintenance of the site during summer operations.

Numerous publications have resulted from the testing carried out at the Lethbridge Wind Research Test Site since its formation (Atkins et al, 1993, 1992, 1991; Baker et al, 1992, 1989, 1987, 1986; Paterson et al, 1990, 1989, 1988, 1987, 1986). Demonstration days and informal tours are held to educate the public and allow manufacturers to present their machines. The response from these demonstration days and publications has helped to shape the direction and test methods presently found at the Test Site. In 1987, a well simulator was designed and constructed to allow for better evaluation of wind and solar systems at pumping depths up to 250 metres. Utilization of this simulator provides performance information required for manufacturers wishing to export their machines overseas.

This report describes the results of the testing carried out over the 1993 test season at the Alberta Renewable Energy Test Site. In many cases, manufacturers carried out modifications to their machines during the testing period. The results presented in this report reflect either the latest configuration or the progressive performance gains of the machines located at the Test Site. The test results of each machine are presented as "stand-alone" sections of the report such that they may be better utilized by the manufacturers. Information on the construction of the Alberta Renewable Energy Test Site can be found in the 1991 Lethbridge Wind Research Test Site Final Report (Atkins et al, 1992).

.0 SITE DESCRIPTION

2.1 Site Overview

The Alberta Renewable Energy Test Site is located five kilometres northeast of Pincher Creek. It is adjacent to a large dugout which provides a continuous source of water for the site. The site was selected for the homogeneity of the surrounding terrain and the availability of water for the pumping circuits. Flat agricultural fields that surround the test site cause a minimal amount of interference with the wind flow.

2.2 Site Layout

Six wind turbine and four photovoltaic water pumping systems were tested in a total of sixteen configurations during the 1993 test season. Two additional wind turbine systems were installed for demonstration and initial evaluation. Complete tests on these two systems is planned for the 1994 test season. One of these was a system developed by a Calgary designer, whose work is being assisted by Dr. Kentfield of the University of Calgary. The unit is a vertical axis, off-set wing design. During the winter months (1993/94) it was relocated to the grounds next to the Mechanical Engineering Department at the University for further investigation. The second system which was installed but not tested in 1993 was the "Little River Pond Mill" which is a small floating wind aeration system. A method of testing is required to test this system (located on the ARETS water supply dugout) during the 1994 test season. The location of all units are shown in Figure 2.1. Tables 2.1 and 2.2 provide summary information on the pumping systems tested. More detailed descriptions are presented with the performance results later in this report.

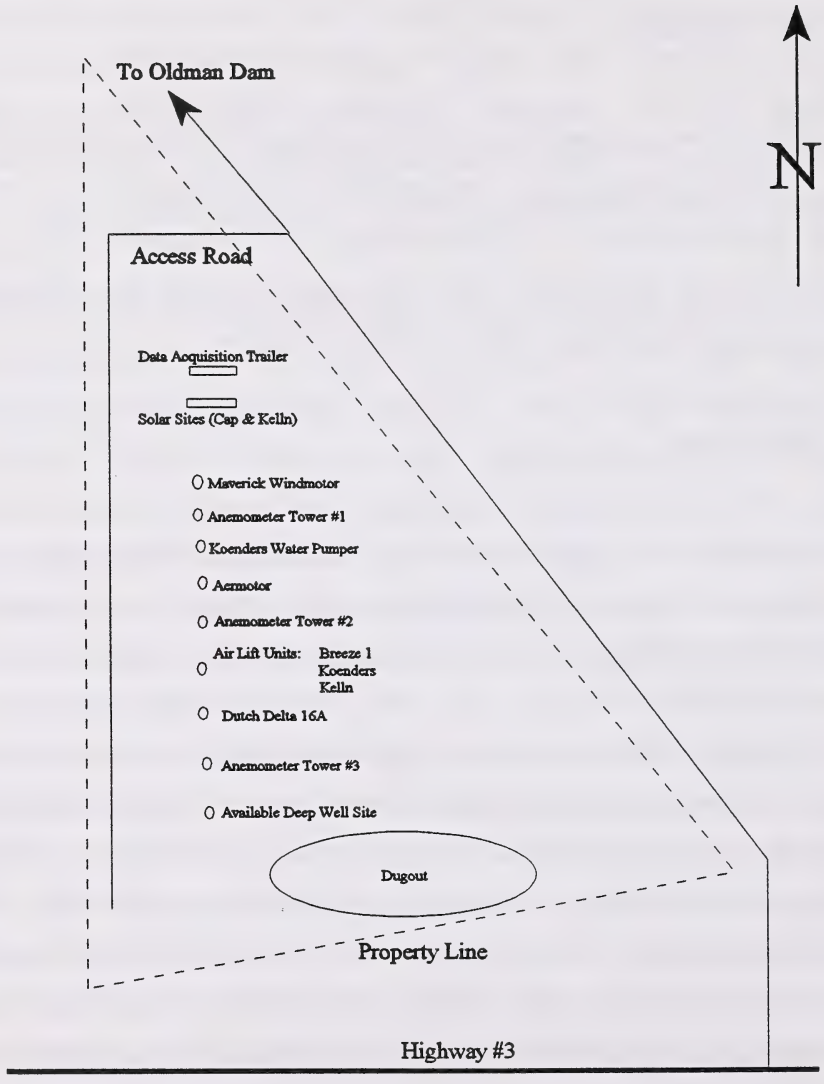

FIGURE 2.1 - LOCATION OF SYSTEMS UNDER TEST AT ARETS (1993)

TABLE 2.1 - WIND PUMPING SYSTEMS TESTED

Model	Description	Supplier
Delta 16A	32-blade delta wing rotor, piston pump driven with a counter balance system	Dutch Industries, Regina, Saskatchewan (306) 949-9522
Koenders (& Koenders Air)	12-blade rotor, direct drive air diaphragm operating proprietary pump.	Koenders Mfg. Co. Ltd. Englefield, Saskatchewan (306) 287-3139
Maverick Windmotor	8-blade delta wing rotor, cable driven progressing cavity pump	Maverick Wind Energy, Pincher Creek, Alberta (403) 627-3630
Aermotor	18-blade rotor, geared down piston pump	Tensigrity Systems Ltd. Metcalfe, Ontario (613) 821-4420
Breeze 1	3-blade rotor, direct drive air diaphragm pump for aeration purposes	Wind Powered Equipment Manning, Alberta (403) 836-3022

2.3 Instrumentation and Monitoring Equipment

To measure the pumping performance of the systems, closed-loop pumping circuits were installed. A schematic of a typical pumping circuit is shown in Figure 2.2. The unit being tested pumps water from one sump, up a predetermined height and into a vented standpipe. The piping used in this portion of the test circuit is sized to be consistent with actual field applications while presenting negligible dynamic head to the pump. The vented

TABLE 2.2 - SOLAR PUMPING SYSTEMS TESTED

Model	Description	Supplier
CAP 3-48-M-F5	3 fixed Siemens photovoltaic panels driving a 4 valve sub-mersible diaphragm pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
CAP 4-48-M-RU	4 fixed Siemens photovoltaic panels driving a floating centrifugal pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
Kelln 6 Panel Water Pump	6 fixed Kyocera photovoltaic panels driving a rotary vane pump	Kelln Consulting Ltd. Lumsden, Sask. (306) 731-2224
Kelln 1 Panel Aerator	1 fixed Kyocera photovoltaic panel driving a piston air compressor	Kelln Consulting Ltd. Lumsden, Sask. (306) 731-2224

standpipe is used to separate air from the pumped water and to dampen the pulsating flows before draining through a flow-metered pipe into the large underground return line. Each of the turbine-type flow meters is equipped with a flow rate register for local readout as well as a pickup for remote sensing. To ensure valid flow readings, the metered pipe is sloped to maintain submergence of the flow meter and is sized to decrease the turbulence in the pumped water before measurement. The design also ensures that the dynamic head developed in this section will not raise the water level in the standpipe to a point where it would contribute to the pumping head of the wind turbine. The water exiting the metered pipe provides potential users with visual evidence of the wind or solar pumper's capabilities. The loop is completed when the pumped water returns to the first sump through the underground connecting pipe.

Atmospheric monitoring for the wind turbines is performed by nearby anemometer towers. An anemometer tower is placed between every two test pump circuits such that it is no further than 15 metres distant from each test pump circuit. Each anemometer tower is 16 metres tall and includes two RM Young 5102 integrated wind speed and direction sensors. The sensors are typically located at heights of 10 and 16 metres. Also installed

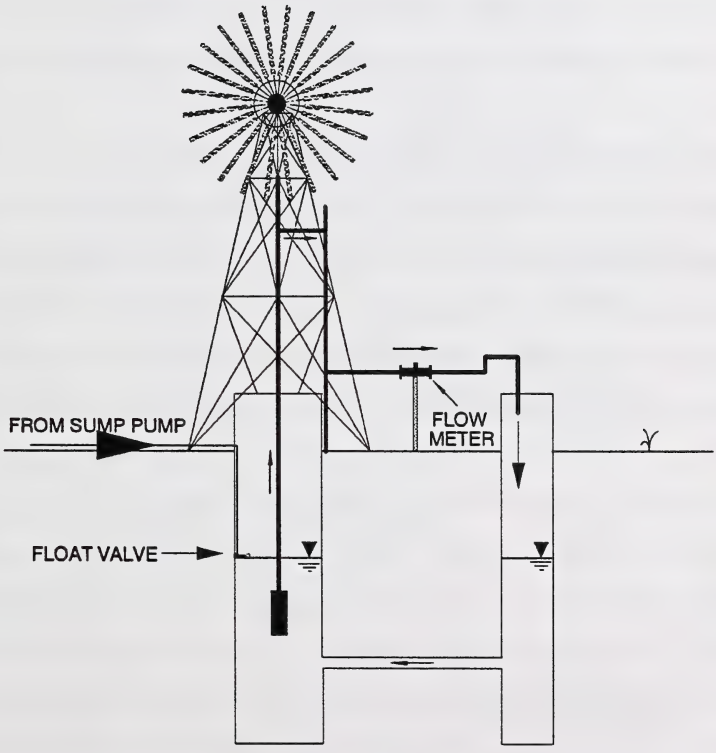

FIGURE 2.2 - TYPICAL PUMPING CIRCUIT

on site is an ambient temperature sensor and an atmospheric pressure sensor. These sensors are used to determine the atmospheric air density.

The incident solar radiation on the solar pumping systems is monitored by Kipp and Zonen pyranometers. The pyranometers are mounted on the framework of the photovoltaic panels.

There are many parameters which can be measured to evaluate the performance of solar and wind turbine pumping systems. It was decided that the performance variables of most interest to users and manufacturers are: the volume flow rate as a function of wind speed and solar energy; the variation of flow with pumping head and the predicted flow volumes in a given solar and wind regime. Infrared photo pickups are also installed on wind systems to monitor their rotor speed or pump cycle speed. The solar systems have voltage and current sensors to monitor the power which is transferred to the pump from the photovoltaic panels.

The monitoring system on the site during 1993 consisted of a SAFE 8000 data acquisition unit and an IBM PC/XT. The SAFE 8000, programmed in an extended BASIC, samples all atmospheric sensors each second and calculates the one and ten minute average and standard deviation of these values. In addition, the one second peak wind gust at the 16 metre levels is also determined on the theory that turbine failure will more likely result from instantaneous high wind gusts than from sustained high average winds. The pulse inputs from the flow meters and photo pickups are totalled at the end of each one and ten minute interval coinciding with the atmospheric measurements. At the end of the ten minute interval, the minimum one minute value over the ten minutes is also determined. This value indicates whether the pumping system began or stopped pumping during that ten minute interval. The results of these calculations are then transmitted to the IBM PC/XT. Both systems are housed in an environmentally controlled trailer located at the north end of the test site. The flow of data through the SAFE 8000 and the IBM PC/XT is illustrated in Figure 2.3.

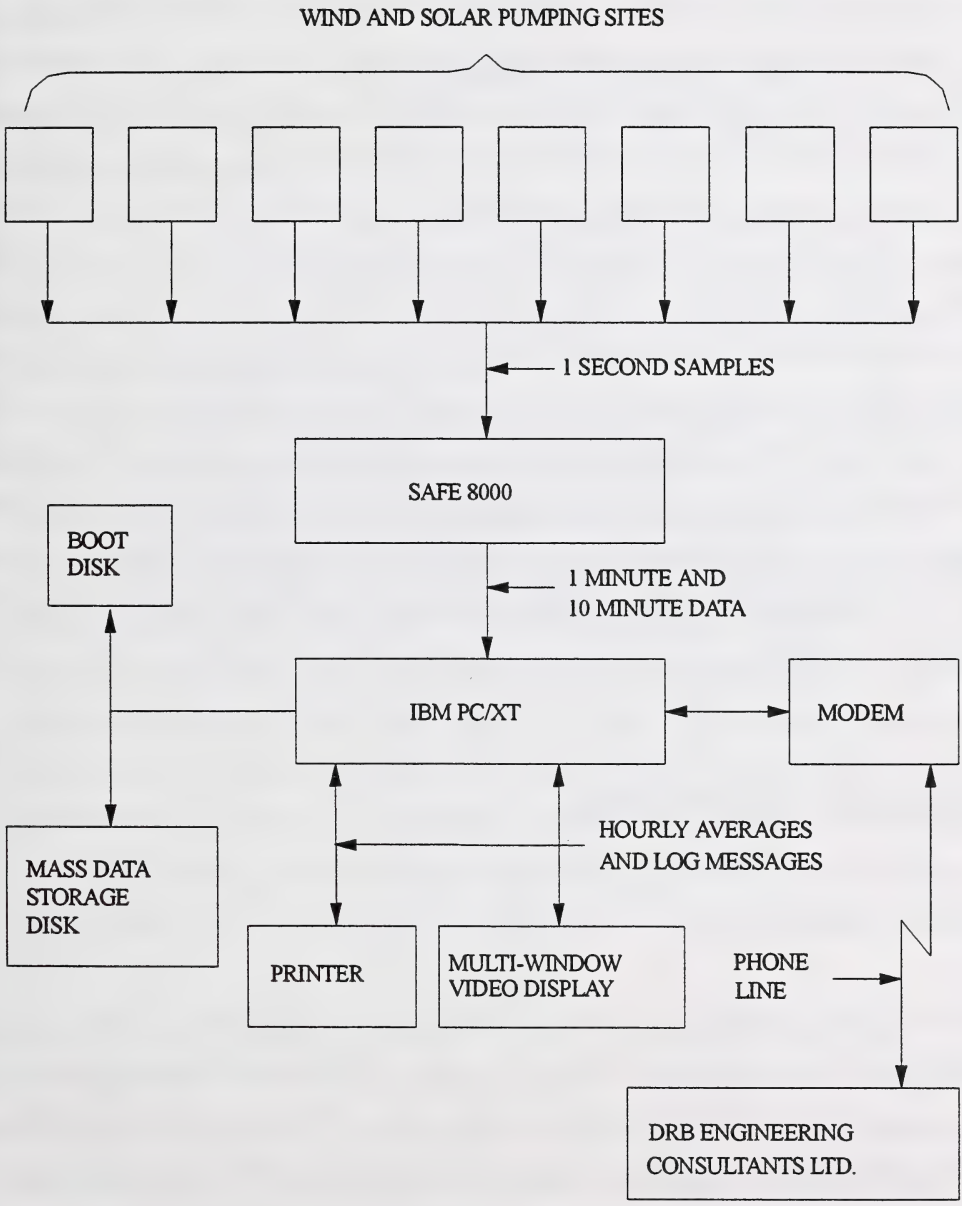

FIGURE 2.3 - DATA ACQUISITION SYSTEM

The IBM uses a UNIX based operating system (QNX) such that it can operate in a multiuser/multitasking environment. A series of scheduled programs, written in C language, is used to facilitate the data collection, processing and transmission. The on-site processing includes producing hourly averages of each sensor input and automatically producing daily summary reports of these values. The ten minute average data is stored on the hard disk (providing thirty days of backup storage), and is regularly retrieved by a remote PC for archiving and analysis. A menu system is provided to on-site and remote users (connected via modem) enabling them to perform a variety of functions. These include manual initiation of the previously discussed automated procedures for any data interval. The user may also obtain, in a similar fashion, data from any of the machines being tested for direct use with a spreadsheet/graphics package such as Lotus 1-2-3. Finally, the menu system allows the user to monitor, in real time, the operation of the site using the one minute data. The operating system is also configured such that password protection prevents unauthorized personnel from modifying the IBM or SAFE software. Because of the UNIX based operating system, all of these tasks can be performed without interrupting the data monitoring process.

3.0 ANALYSIS PROCEDURES

3.1 Reliability

One of the most important factors in evaluating a pumping system is its reliability. Therefore, the test site maintains operating logs of each machine. These logs include their installation date and down times due to machine repair. The logs are used to calculate the number of days the machines were tested and the fraction of time during this test period the machines were available for operation (regardless of wind or cloud conditions). This data is presented with the performance data of each system.

3.2 Wind Performance Curves

The monitoring and analysis procedures at the test site adheres to the Canadian Standards Association (CSA) Standard F417-M91 "Wind Energy Conversion Systems (WECS)-Performance".

The collected data was first divided into separate files for each machine. These files were then filtered for invalid data sets caused by machine or monitoring failures. The wind turbine files were also filtered for data sets in which the anemometers or the machine could have been shaded by surrounding turbines.

After the above two filtering methods were applied to the data files, the data sets were divided into wind speed bins. For wind speeds less than 8 m/s, the width of each wind speed bin was 0.5 m/s; for winds greater than 8 m/s, the bin width was 1.0 m/s. This increased interval still agrees with the CSA standard and was applied due to the decreased amount of data recorded above 8 m/s. The mean and standard deviation of each recorded parameter was then calculated for each wind speed bin. The results were then used for the final filtering process. Chauvenet's criterion (Holman, 1978) allows the elimination of spurious data with unknown origins which is greater than approximately two standard deviations away from the mean within each wind speed bin. This criterion was applied as per the CSA standard to the measured flow rates and, if monitored, the rotor speeds. The averages and standard deviations for all parameters in each wind speed bin were then recalculated.

A final test specified by the CSA standard to determine the statistical validity of the data was applied before graphing the results. This final test checks to see if the data meets specified minimum data base requirements (MDBR) and is defined as follows:

1) For wind speed bins in which the parameter to be graphed (flow rate or rotor speed) is less than 25% of the maximum or rated value, then the bin shall not meet the MDBR until at least forty 10 minute averages (samples) are obtained. This controls the data such that the true mean of the bin is contained within a

confidence interval of 1 standard deviation of the sample mean with a probability of 0.99.

2) For wind speed bins less than 15 m/s, the bin does not satisfy the MDBR until; (a) there is at least ten samples in the bin, (b) there is a probability of 0.99 that the true mean of the bin is within 10% of the sample mean. The method for determining this value is presented in detail in the CSA standard.
3) For wind speed bins greater than 15 m/s, the bin does not satisfy the MDBR until; (a) there is at least ten samples in the bin, (b) there is a probability of 0.99 that the true mean of the bin is within 20% of the sample mean. This calculation is a slight variation of the above.

The results of the MDBR test, along with the average and standard deviations of each parameter within each bin are tabulated and presented with the performance results. Smooth curves of the data are generated by fitting fifth order polynomial equations to the tabulated values. The coefficients of the resulting equations are then used for subsequent volume yield calculations.

3.3 Monthly Pumping Estimates

The final calculation made from the performance curves is the potential monthly pumping estimates. These estimates are based on the pumping system being available for operation whenever the wind speed exceeds the cut-in speed of the system. They are also based on wind regimes which display Rayleigh characteristics. That is, the frequency of time winds are found within any wind speed interval (e.g. from v_x to v_y) may be calculated by incorporating the mean wind speed ($\overline{v}$) in the following equation:

$$F(v_x \le v \le v_y) = \exp\left[-\left(\frac{\pi}{4}\right)\left(\frac{v_x}{\overline{v}}\right)^2\right] - \exp\left[-\left(\frac{\pi}{4}\right)\left(\frac{v_y}{\overline{v}}\right)^2\right]$$

To calculate the wind turbine's monthly pumping potential, the flow rate values determined by the fifth order polynomial fit to the binned data is integrated with the fraction of time (F) that the wind would blow within each wind speed interval. The sum of these values is equal to the average pumping rate of the wind turbine. The potential volume the system could pump is then determined by multiplying this average with the time period in question (this study uses 30 day months). Repeating this calculation for a variety of mean wind speeds allows the graphing of the monthly pumping potential against mean wind speed.

3.4 Solar Performance Curves

Performance curves for the solar pumping systems were determined by the same algorithm as the wind pump systems. The only specific changes were:

1) the solar files were filtered for invalid data sets caused by the pyranometers and/or photovoltaic panels being shaded by a nearby utility pole.
2) the performance data was divided into solar radiation intensity bins. For solar radiation values less than 800 W/m^2, the width of each bin was 50 W/m^2; for solar radiation values greater than 800 W/m^2, the width of each bin was 100 W/m^2.
3) no monthly pumping yields were determined because of the lack of a standard method of describing the distribution of solar radiation intensity values.

.0 PRESENTATION AND DISCUSSION OF RESULTS

The following section presents and discusses the performance characteristics of the pumping ystems tested. The machines are discussed in alphabetical order according to the manufacturer's ame and are presented as "pull-out" sections. Each "Specification and Performance Summary" age has a corresponding "Method of Bin Results" page. In the case of the wind turbine tables

the air density observed in each wind speed bin is reported. In accordance with the CSA performance testing standard, the performance data have not been adjusted to standard atmospheric conditions.

The summary tables for the solar pumping systems indicate the average wind speed and ambient air temperature at which the data was recorded. These two parameters will affect the surface temperature that the photovoltaic panels attain during the test. This is important as the performance of the photovoltaic panels are affected by their surface temperature. However, as with the air density effect on wind turbines, no performance correction has been made for the panel temperature effect on the solar systems.

ALBERTA RENEWABLE ENERGY TEST SITE
1993 TEST RESULTS OF THE
KOENDERS WINDMILLS

Koenders Manufacturing Company Ltd. is located in Englefeld, Saskatchewan. This is their econd year of testing on the test site. The company manufactures both a water pumping windmill nd an aerating windmill. Both systems have identical heads, the only alteration is in the down ole equipment. The windmills consists of 12 blades mounted on a horizontal shaft. Their 1.5 netre diameter rotors are made of galvanized steel. The rotors are directly linked to a 200 mm iameter diaphragm that provides a 19 mm stroke per revolution. The manufacturer reports that 0 psi is developed by this diaphragm. The pressurized air is either injected into the water body r is delivered to an air operated pump. The pump was designed and is manufactured at the Koender's fabrication plant. The air entering the pump forces water out of the system and is then eleased into the surrounding water source. While this occurs, a gasket/float system allows the ump to refill with water by hydraulic pressure. Once filled, the gasket/float system causes the tart of the next cycle.

WATER PUMPING WINDMILL

In 1992, ARETS determined that the performance of the pump was sometimes sporadic. During 1993 a number of modifications were made on the pump to determine its effect on performance and on reliability. The specification sheet shows the results of three test configurations. The pump performed best with flapper/check valves installed in the air inlet, air outlet and water outlet lines. Further enhancements in performance were found when the pump was located near the surface, however in this instance the pump also became sporadic. It would appear the pump needs a certain amount of submergence to maintain backpressure on the various valves, otherwise the pump can get stuck in midcycle. Koender's plans to utilize this information

to provide a new pump to test for the 1994 test season.

Monthly expected water yields were only calculated for the optimum configuration. The graph shows that at a 5 m/s monthly average wind speed, the farmer should expect this unit to deliver approximately 200 cubic metres of water. Using a typical requirement for range cattle of 54 litres per cow per day, this would be sufficient so supply water for 123 cows. This assumes no losses (evaporation, wastage, etc.) and sufficient storage to handle all water pumped.

AERATION WINDMILL

The aeration windmill was installed in June of the 1993 test season. It ran without any problems during the entire test season. Unlike the Breeze aeration turbine tested in 1993, the Koenders aeration windmill was relatively insensitive to the submergence level. At both 1.5 and 3.0 metre submergence levels the wind turbine began operating at approximately 1.5 m/s. At 1.5 metres submergence, the windmill had a peak air output of 35 litres/minute, while at 3.0 metres submergence the windmill had a peak air output of 25 litres/minute.

ARETS has an ongoing research project into determining how the performance of aerators can best be quantified. For 1993, ARETS introduces in the aerator's specification sheets the amount of air which would be expected to be pumped during a month for various average wind speeds. The application of these results in determining the size of dug out which this unit could maintain its water quality would be very site specific, but this should provide the agricultural specialist with a starting point for assessing the various wind powered aeration systems.

METHOD OF BIN RESULTS FOR: KOENDERS WATER PUMPER PUMPING AGAINST A 3 METRE HEAD WITH 4 METRES SUBMERGENCE AND A FLAPPER VALVE ON THE WATER OUTLET

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--BIN SAMPLE AVERAGE-- AIR DENSITY KG/M^3	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	38	1.058	1.74	0.26	0.18	0.13	N
2	2.0 TO 2.5	145	1.060	2.28	0.42	0.14	0.25	Y
3	2.5 TO 3.0	274	1.061	2.75	0.73	0.14	0.42	Y
4	3.0 TO 3.5	351	1.062	3.25	1.16	0.14	0.55	Y
5	3.5 TO 4.0	397	1.065	3.74	1.67	0.14	0.63	Y
6	4.0 TO 4.5	414	1.068	4.23	2.13	0.15	0.68	Y
7	4.5 TO 5.0	321	1.068	4.74	2.71	0.14	0.63	Y
8	5.0 TO 5.5	347	1.071	5.24	3.17	0.15	0.55	Y
9	5.5 TO 6.0	271	1.070	5.73	3.68	0.14	0.53	Y
10	6.0 TO 6.5	236	1.067	6.24	4.23	0.15	0.46	Y
11	6.5 TO 7.0	229	1.064	6.73	4.70	0.15	0.42	Y
12	7.0 TO 7.5	211	1.062	7.24	5.11	0.14	0.39	Y
13	7.5 TO 8.0	176	1.057	7.73	5.53	0.13	0.39	Y
14	8.0 TO 9.0	219	1.053	8.41	6.12	0.27	0.45	Y
15	9.0 TO 10.0	150	1.055	9.46	6.89	0.30	0.41	Y
16	10.0 TO 11.0	87	1.054	10.52	7.30	0.32	0.51	Y
17	11.0 TO 12.0	57	1.054	11.42	7.86	0.27	0.45	Y
18	12.0 TO 13.0	39	1.053	12.42	8.29	0.27	0.34	Y
19	13.0 TO 14.0	26	1.048	13.59	8.86	0.28	0.44	Y
20	14.0 TO 15.0	20	1.044	14.45	9.38	0.28	0.37	Y
21	15.0 TO 16.0	11	1.043	15.51	9.74	0.26	0.30	Y
22	16.0 TO 17.0	5	1.053	16.14	9.74	0.16	0.31	N
23	17.0 TO 18.0	-	-	-	-	-	-	N
24	18.0 TO 19.0	-	-	-	-	-	-	N

TOTAL NUMBER OF
REDUCED DATA SETS: 4024
AVERAGE TEMPERATURE
DURING THE TEST: 289.0 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.19 KPA

METHOD OF BIN RESULTS FOR: KOENDERS WATER PUMPER PUMPING AGAINST A 5.5 METRE HEAD WITH 4 METRES SUBMERGENCE AND NO FLAPPER VALVE ON THE WATER OUTLET

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--BIN SAMPLE AVERAGE-- AIR DENSITY KG/M^3	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	13	1.061	1.73	0.27	0.19	0.11	N
2	2.0 TO 2.5	55	1.056	2.29	0.43	0.14	0.36	Y
3	2.5 TO 3.0	118	1.058	2.79	0.55	0.14	0.28	Y
4	3.0 TO 3.5	216	1.057	3.27	0.77	0.15	0.38	Y
5	3.5 TO 4.0	257	1.057	3.75	1.02	0.14	0.51	Y
6	4.0 TO 4.5	268	1.060	4.24	1.32	0.15	0.52	Y
7	4.5 TO 5.0	229	1.068	4.74	1.50	0.14	0.52	Y
8	5.0 TO 5.5	225	1.068	5.25	1.93	0.14	0.55	Y
9	5.5 TO 6.0	264	1.071	5.73	2.28	0.14	0.38	Y
10	6.0 TO 6.5	200	1.069	6.23	2.66	0.16	0.31	Y
11	6.5 TO 7.0	178	1.069	6.73	3.00	0.14	0.26	Y
12	7.0 TO 7.5	176	1.067	7.24	3.26	0.15	0.21	Y
13	7.5 TO 8.0	148	1.065	7.73	3.52	0.15	0.25	Y
14	8.0 TO 9.0	233	1.066	8.44	3.84	0.29	0.27	Y
15	9.0 TO 10.0	142	1.064	9.44	4.19	0.30	0.25	Y
16	10.0 TO 11.0	50	1.068	10.45	4.56	0.31	0.28	Y
17	11.0 TO 12.0	40	1.068	11.59	4.97	0.26	0.25	Y
18	12.0 TO 13.0	20	1.060	12.45	5.11	0.27	0.13	Y
19	13.0 TO 14.0	13	1.065	13.38	5.41	0.28	0.21	Y
20	14.0 TO 15.0	4	1.066	14.47	5.68	0.25	0.18	N
21	15.0 TO 16.0	-	-	-	-	-	-	N
22	16.0 TO 17.0	-	-	-	-	-	-	N
23	17.0 TO 18.0	-	-	-	-	-	-	N
24	18.0 TO 19.0	-	-	-	-	-	-	N

TOTAL NUMBER OF
REDUCED DATA SETS: 2852
AVERAGE TEMPERATURE
DURING THE TEST: 288.8 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.19 KPA

METHOD OF BIN RESULTS FOR: KOENDERS WATER PUMPER PUMPING AGAINST A 3 METRE HEAD WITH MINIMAL SUBMERGENCE AND A FLAPPER VALVE ON THE WATER OUTLET

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--BIN SAMPLE AVERAGE-- AIR DENSITY KG/M^3	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	62	1.077	1.64	0.50	0.26	0.33	Y
2	2.0 TO 2.5	81	1.082	2.27	1.17	0.14	0.58	Y
3	2.5 TO 3.0	116	1.082	2.75	1.86	0.15	0.86	Y
4	3.0 TO 3.5	144	1.087	3.24	2.53	0.14	1.17	Y
5	3.5 TO 4.0	97	1.091	3.74	3.52	0.14	1.01	Y
6	4.0 TO 4.5	101	1.094	4.27	4.26	0.15	1.06	Y
7	4.5 TO 5.0	143	1.092	4.76	4.86	0.15	0.84	Y
8	5.0 TO 5.5	166	1.090	5.28	5.46	0.14	0.70	Y
9	5.5 TO 6.0	165	1.081	5.75	6.05	0.15	0.68	Y
10	6.0 TO 6.5	160	1.081	6.26	6.69	0.15	0.57	Y
11	6.5 TO 7.0	179	1.081	6.74	7.32	0.14	0.51	Y
12	7.0 TO 7.5	143	1.074	7.24	7.86	0.14	0.43	Y
13	7.5 TO 8.0	106	1.076	7.73	8.29	0.15	0.56	Y
14	8.0 TO 9.0	158	1.065	8.39	9.01	0.30	0.47	Y
15	9.0 TO 10.0	54	1.045	9.46	9.78	0.26	0.48	Y
16	10.0 TO 11.0	43	1.042	10.44	10.44	0.27	0.44	Y
17	11.0 TO 12.0	36	1.042	11.38	11.10	0.24	0.33	Y
18	12.0 TO 13.0	22	1.047	12.49	11.71	0.31	0.25	Y
19	13.0 TO 14.0	25	1.041	13.54	12.14	0.27	0.21	Y
20	14.0 TO 15.0	20	1.037	14.38	12.45	0.26	0.23	Y
21	15.0 TO 16.0	9	1.045	15.43	12.93	0.27	0.18	N
22	16.0 TO 17.0	2	1.045	16.81	13.52	0.06	0.05	N
23	17.0 TO 18.0	6	1.049	17.70	13.62	0.30	0.11	N
24	18.0 TO 19.0	2	1.050	18.41	13.76	0.12	0.00	N

TOTAL NUMBER OF
REDUCED DATA SETS: 2042
AVERAGE TEMPERATURE
DURING THE TEST: 285.4 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.26 KPA

METHOD OF BIN RESULTS FOR: KOENDERS AERATOR INJECTING AIR AT 1.5 METRE SUBMERGENCE

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--BIN SAMPLE AVERAGE-- AIR DENSITY KG/M^3	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	288	1.058	1.67	1.53	0.24	1.06	Y
2	2.0 TO 2.5	439	1.063	2.25	3.22	0.14	1.43	Y
3	2.5 TO 3.0	604	1.064	2.76	4.70	0.14	1.65	Y
4	3.0 TO 3.5	674	1.065	3.25	6.31	0.14	1.54	Y
5	3.5 TO 4.0	664	1.066	3.74	7.48	0.14	1.51	Y
6	4.0 TO 4.5	647	1.067	4.23	8.71	0.14	1.41	Y
7	4.5 TO 5.0	538	1.067	4.75	9.87	0.14	1.26	Y
8	5.0 TO 5.5	518	1.070	5.24	10.99	0.14	1.20	Y
9	5.5 TO 6.0	478	1.070	5.74	12.28	0.15	1.21	Y
10	6.0 TO 6.5	412	1.066	6.24	13.67	0.14	1.18	Y
11	6.5 TO 7.0	379	1.064	6.75	15.22	0.15	1.08	Y
12	7.0 TO 7.5	342	1.061	7.23	16.55	0.14	1.03	Y
13	7.5 TO 8.0	278	1.061	7.74	17.61	0.14	1.18	Y
14	8.0 TO 9.0	382	1.058	8.45	19.43	0.29	1.33	Y
15	9.0 TO 10.0	238	1.061	9.45	21.67	0.29	1.28	Y
16	10.0 TO 11.0	120	1.064	10.45	23.85	0.28	1.01	Y
17	11.0 TO 12.0	103	1.066	11.49	25.86	0.27	1.00	Y
18	12.0 TO 13.0	74	1.068	12.48	27.47	0.27	0.96	Y
19	13.0 TO 14.0	58	1.071	13.45	28.70	0.29	0.96	Y
20	14.0 TO 15.0	50	1.070	14.49	30.28	0.25	0.97	Y
21	15.0 TO 16.0	42	1.072	15.46	31.56	0.31	0.95	Y
22	16.0 TO 17.0	19	1.071	16.32	32.74	0.26	0.85	Y
23	17.0 TO 18.0	6	1.074	17.38	34.40	0.23	1.12	N
24	18.0 TO 19.0	14	1.073	18.51	35.38	0.33	0.85	Y

TOTAL NUMBER OF
REDUCED DATA SETS: 7380
AVERAGE TEMPERATURE
DURING THE TEST: 288.6 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.20 KPA

METHOD OF BIN RESULTS FOR: KOENDERS AERATOR INJECTING AIR AT 3.0 METRE SUBMERGENCE

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--BIN SAMPLE AVERAGE-- AIR DENSITY KG/M^3	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	155	1.071	1.63	0.94	0.25	0.63	Y
2	2.0 TO 2.5	150	1.081	2.27	2.11	0.14	1.08	Y
3	2.5 TO 3.0	201	1.087	2.76	3.55	0.15	1.50	Y
4	3.0 TO 3.5	201	1.091	3.25	4.96	0.14	1.33	Y
5	3.5 TO 4.0	152	1.092	3.74	6.27	0.14	1.45	Y
6	4.0 TO 4.5	143	1.092	4.24	7.43	0.15	1.31	Y
7	4.5 TO 5.0	207	1.091	4.75	8.69	0.15	1.15	Y
8	5.0 TO 5.5	197	1.086	5.24	9.52	0.14	1.06	Y
9	5.5 TO 6.0	207	1.083	5.74	10.53	0.15	0.98	Y
10	6.0 TO 6.5	199	1.079	6.24	11.72	0.14	1.00	Y
11	6.5 TO 7.0	227	1.078	6.74	12.66	0.13	0.89	Y
12	7.0 TO 7.5	178	1.073	7.24	13.63	0.15	0.85	Y
13	7.5 TO 8.0	173	1.081	7.74	14.76	0.15	0.77	Y
14	8.0 TO 9.0	193	1.069	8.41	15.99	0.27	0.93	Y
15	9.0 TO 10.0	88	1.050	9.46	17.59	0.29	0.82	Y
16	10.0 TO 11.0	73	1.046	10.51	19.10	0.27	0.80	Y
17	11.0 TO 12.0	59	1.039	11.43	20.41	0.27	0.66	Y
18	12.0 TO 13.0	31	1.046	12.57	21.50	0.28	0.82	Y
19	13.0 TO 14.0	22	1.044	13.49	22.64	0.24	0.59	Y
20	14.0 TO 15.0	20	1.037	14.30	23.42	0.25	0.69	Y
21	15.0 TO 16.0	9	1.044	15.50	24.42	0.18	0.53	N
22	16.0 TO 17.0	4	1.047	16.60	25.49	0.38	0.36	N
23	17.0 TO 18.0	6	1.049	17.58	26.49	0.28	0.38	N
24	18.0 TO 19.0	-	-	-	-	-	-	N

TOTAL NUMBER OF
REDUCED DATA SETS: 2897
AVERAGE TEMPERATURE
DURING THE TEST: 285.5 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.31 KPA

KOENDERS

MANUFACTURER and DISTRIBUTOR:

Koenders Mfg. Co. Ltd.
P.O. Box 171
Englefield, Saskatchewan, Canada
S0K 1N0
(306) 287-3139

PERFORMANCE:

Testing Period: 242 days
Period Operational:233 days
Percent Availability:96 %

INSTALLED: June 24,1992

FIGURE 1. Koenders Wind Turbine.

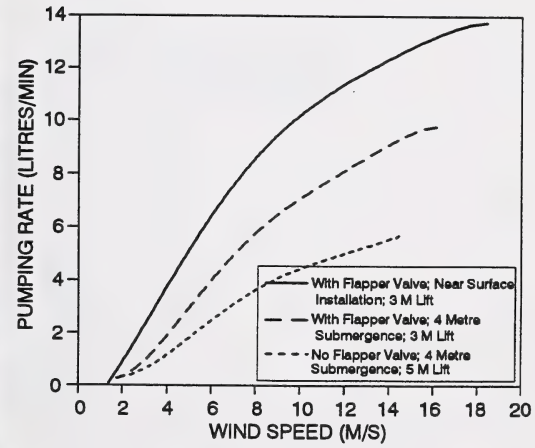

FIGURE 2. Pumping Rate versus Wind Speed for Various Configurations

PHYSICAL DESCRIPTION:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 5.1 ft. (1.57 m)
Swept Area: 21 ft² (1.948 m²)
Number of Blades: 12
Blade Design: proprietary
Blade Material: galvanized steel
Hub Height: 12 ft. (3.66 m)
Transmission: direct drive
Pump Type: air operated proprietary system
Pumping System Description:
windmill driven diaphragm injects air into pump

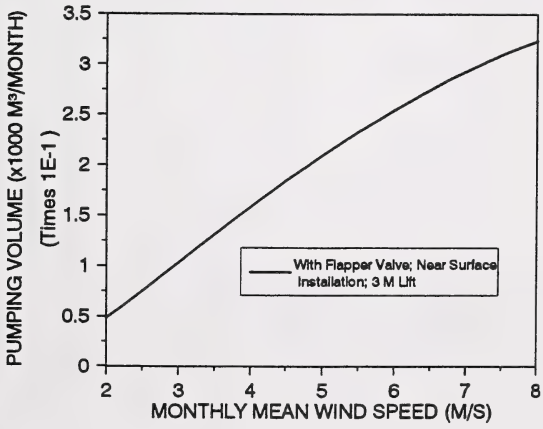

FIGURE 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

KOENDERS AERATION TURBINE

MANUFACTURER and DISTRIBUTOR:

Koenders Mfg. Co. Ltd.
P.O. Box 171
Englefield, Saskatchewan, Canada
S0K 1N0
(306) 287-3139

PERFORMANCE:

Testing Period: 128 days
Period Operational:128 days
Percent Availability:100 %

INSTALLED: June 3, 1993

FIGURE 1. Koenders Aeration Turbine.

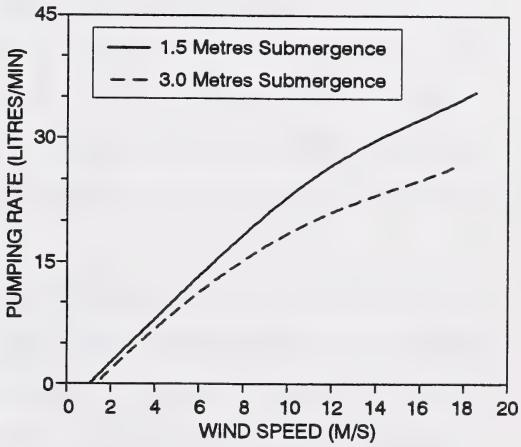

FIGURE 2. Airflow Rate versus Wind Speed for 1.5 M and 3.0 M Submergence

PHYSICAL DESCRIPTION:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 5.1 ft. (1.57 m)
Swept Area: 21 ft² (1.948 m²)
Number of Blades: 12
Blade Design: proprietary
Blade Material: galvanized steel
Hub Height: 12 ft. (3.66 m)
Transmission: direct drive
Pump Type: diaphragm
Pump Size: diaphragm dia. 8 in. (203 mm)
Stroke: 0.75 in. (19.05 mm)
Pumping System Description:
diaphragm pump injects air into water

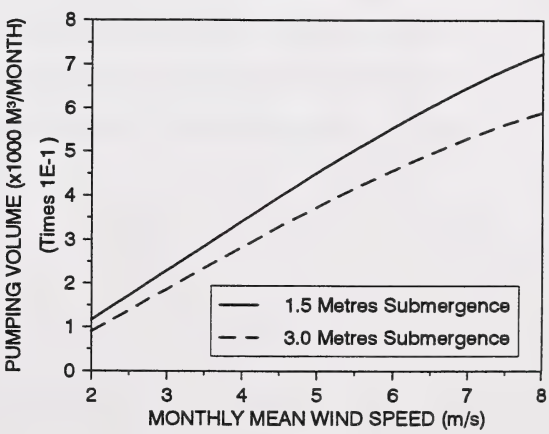

FIGURE 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

ALBERTA RENEWABLE ENERGY TEST SITE
1993 TEST RESULTS OF THE
MAVERICK WINDMOTOR

The Maverick Windmotor has been tested under several configurations since 1987. In 1993 ARETS performed its second year of testing the Windmotor with a upwind delta-wind configuration. This unit is a eight-bladed machine with a rotor diameter of 2.44 m. It is manufactured in Pincher Creek, Alberta and incorporates a high-speed version of the delta-wing rotor developed at the University of Calgary. The two stage helical progressive cavity pump is driven directly by the rotor via a flexible cable.

The turbine operates at rotor speeds in excess of 300 RPM and does not begin furling until 15 m/s. These are extremely high numbers for mechanical water pumping systems, but they do not seem to have a negative impact on the unit's reliability. This year, as with 1992, it ran without any mechanical problems. Its performance numbers, however, did drop slightly (approx. 10%), which was likely caused by a "looser" fit of the helical rotor caused by wear to the stator. During 1993, its peak output was 80 litres per minute and its overall performance curve would result in 800 cubic metres of water being pumped per month at locations with an average wind speed of 5 m/s. Using a typical requirement for range cattle of 54 litres per cow per day, this would be sufficient so supply water for 493 cows. This assumes no losses (evaporation, wastage, etc.) and sufficient storage to handle all water pumped.

METHOD OF BIN RESULTS FOR: MAVERICK WINDMOTOR PUMPING AGAINST A 5.5 METRE HEAD

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--- BIN SAMPLE AVERAGE ---- AIR DENSITY KG/M^3	WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS ROTOR SPEED	FLOW RATE
1	1.5 TO 2.0	314	1.062	1.64	6.0	0.51	0.25	3.5	0.84	Y	Y
2	2.0 TO 2.5	380	1.063	2.26	10.0	1.61	0.14	6.3	1.53	Y	Y
3	2.5 TO 3.0	561	1.066	2.77	18.8	3.83	0.14	10.7	2.62	Y	Y
4	3.0 TO 3.5	679	1.068	3.25	33.6	7.54	0.14	13.3	3.29	Y	Y
5	3.5 TO 4.0	686	1.070	3.75	55.3	12.93	0.15	10.2	2.58	Y	Y
6	4.0 TO 4.5	655	1.072	4.24	73.0	17.34	0.14	8.1	2.05	Y	Y
7	4.5 TO 5.0	597	1.072	4.74	88.0	21.06	0.14	7.5	1.89	Y	Y
8	5.0 TO 5.5	625	1.072	5.25	101.9	24.47	0.15	6.4	1.58	Y	Y
9	5.5 TO 6.0	546	1.070	5.73	115.3	27.74	0.14	6.6	1.63	Y	Y
10	6.0 TO 6.5	433	1.067	6.24	129.3	31.14	0.15	6.5	1.57	Y	Y
11	6.5 TO 7.0	402	1.067	6.73	142.6	34.39	0.14	6.0	1.43	Y	Y
12	7.0 TO 7.5	395	1.064	7.25	155.8	37.57	0.15	6.3	1.49	Y	Y
13	7.5 TO 8.0	347	1.061	7.73	167.9	40.49	0.14	6.0	1.45	Y	Y
14	8.0 TO 9.0	522	1.059	8.44	185.8	44.94	0.29	8.6	2.08	Y	Y
15	9.0 TO 10.0	333	1.059	9.46	211.7	51.40	0.29	9.4	2.29	Y	Y
16	10.0 TO 11.0	166	1.058	10.51	238.1	58.23	0.31	9.6	2.53	Y	Y
17	11.0 TO 12.0	139	1.061	11.44	259.7	64.22	0.27	9.2	2.76	Y	Y
18	12.0 TO 13.0	90	1.064	12.41	280.5	70.80	0.27	8.7	2.79	Y	Y
19	13.0 TO 14.0	74	1.068	13.50	298.0	76.74	0.30	8.1	2.50	Y	Y
20	14.0 TO 15.0	56	1.068	14.54	304.6	79.21	0.27	14.5	4.22	Y	Y
21	15.0 TO 16.0	37	1.071	15.45	297.8	77.88	0.29	28.6	8.28	Y	Y
22	16.0 TO 17.0	25	1.070	16.32	266.2	69.53	0.25	54.3	14.83	Y	Y
23	17.0 TO 18.0	9	1.074	17.55	130.9	31.31	0.26	69.7	19.23	N	N
24	18.0 TO 19.0	12	1.073	18.53	95.8	21.07	0.29	32.5	8.84	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 8109
AVERAGE TEMPERATURE
DURING THE TEST: 288.2 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.22 KPA

MAVERICK WINDMOTOR

MANUFACTURER and DISTRIBUTOR:

Maverick Wind Energy Ltd.
P.O. Box 2707
Pincher Creek, Alberta, Canada
T0K 1W0
(403) 627-3630
(403) 627-3091

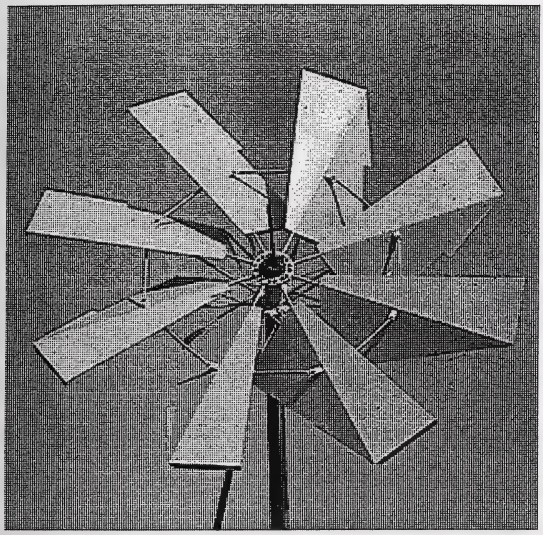

FIGURE 1. Maverick Windmotor Wind Turbine.

PHYSICAL DESCRIPTION:

Turbine Type: downwind
Axis: horizontal
Rotor Diameter: 8 ft. (2.44 m)
Swept Area: 50.4 ft² (4.68 m²)
Number of Blades: 8
Blade Design: high speed delta
Blade Material: sheet metal
Hub Height: 25 ft. (7.62 m)
Transmission: direct drive
Gear Ratio: 1 : 1
Pump Type: helical progressing cavity
Pump Size: 4.5 in. (114.3 mm) diameter
Pumping System Description:
direct cable drive from
rotor to pump

PERFORMANCE:

Testing Period: 224 days
Period Operational:224 days
Percent Availability:100 %

INSTALLED: July 9, 1992

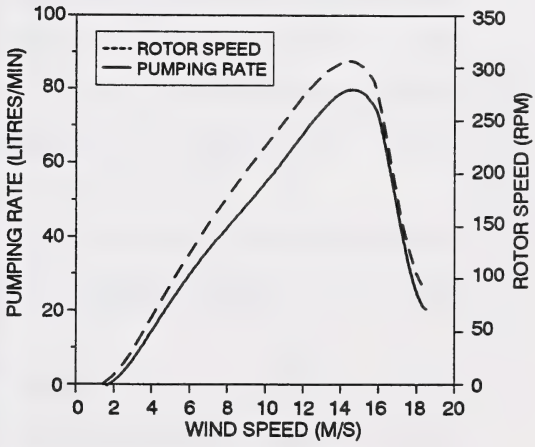

FIGURE 2. Pumping Rate and Rotor Speed versus Wind Speed for an 18 foot (5.5m) Lift.

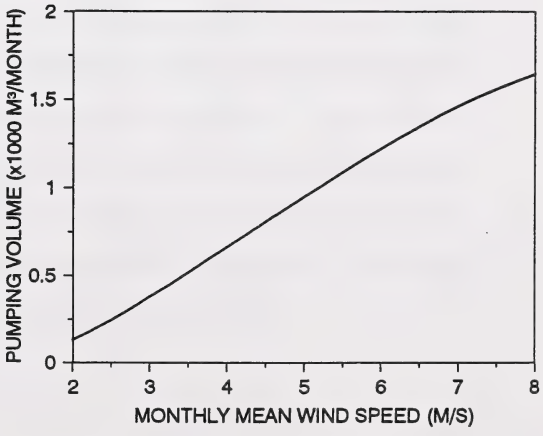

FIGURE 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

ALBERTA RENEWABLE ENERGY TEST SITE
1993 TEST RESULTS OF THE
AERMOTOR

The Aermotor is manufactured in the United States and is distributed by Tensegrity Systems Limited of Metcalf, Ontario. It is a commercial machine which has been available for many years. It was installed on the site to assist the Canadian distributor in developing a local market as well as to provide a baseline which Canadian manufacturers can reference their system's performance.

The Aermotor consists of an upwind 18 bladed rotor which drives a reciprocating piston pump through a gear reduction system of 3.29:1. The pump tested had a stroke of 18.5 cm and a diameter of 10.2 cm.

The performance of the unit this year was almost identical to that of the 1992 test season. Its cut-in wind speed was found to be 1.7 m/s and its cut-out speed was approximately 18.5 m/s. Its peak output was measured at 46 litres/minute at an average wind speed of 8.4 m/s when pumping against a 5.5 metre lift. The pump yield curve shows that this turbine can pump 1100 cubic metres of water per month at locations with a 5 m/s average monthly wind speed. Using a typical requirement for range cattle of 54 litres per cow per day, this would be sufficient so supply water for 679 cows. This assumes no losses (evaporation, wastage, etc.) and sufficient storage to handle all water pumped. The unit was operational for the entire season, indicating excellent reliability. The unit was operational from June 18 to October 6, 1993. The late spring start was caused by the ARETS staff not storing the pump properly for the season. Some water had been left in the pump which froze and burst the top poppet valve housing.

METHOD OF BIN RESULTS FOR: AERMOTOR #802-8
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--- BIN SAMPLE AVERAGE ---- AIR DENSITY KG/M^3	WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS ROTOR SPEED	FLOW RATE
1	1.5 TO 2.0	23	1.068	1.72	6.6	3.19	0.17	3.3	1.67	N	N
2	2.0 TO 2.5	92	1.062	2.26	10.5	5.06	0.14	5.4	2.62	Y	Y
3	2.5 TO 3.0	262	1.066	2.79	16.7	8.07	0.14	8.0	3.87	Y	Y
4	3.0 TO 3.5	513	1.068	3.26	27.9	13.40	0.13	10.1	4.91	Y	Y
5	3.5 TO 4.0	561	1.071	3.75	39.8	19.01	0.14	7.9	3.86	Y	Y
6	4.0 TO 4.5	591	1.073	4.24	48.5	23.12	0.14	7.3	3.61	Y	Y
7	4.5 TO 5.0	621	1.075	4.75	57.0	27.25	0.15	6.5	3.21	Y	Y
8	5.0 TO 5.5	543	1.076	5.24	64.8	30.96	0.14	4.3	2.07	Y	Y
9	5.5 TO 6.0	479	1.074	5.74	72.4	34.56	0.15	4.4	2.11	Y	Y
10	6.0 TO 6.5	461	1.072	6.25	79.8	38.11	0.14	3.5	1.73	Y	Y
11	6.5 TO 7.0	458	1.071	6.74	85.8	40.99	0.14	3.1	1.47	Y	Y
12	7.0 TO 7.5	394	1.066	7.25	90.5	43.21	0.14	2.4	1.15	Y	Y
13	7.5 TO 8.0	307	1.071	7.73	94.0	44.91	0.15	2.4	1.14	Y	Y
14	8.0 TO 9.0	403	1.061	8.43	96.6	46.12	0.29	2.4	1.12	Y	Y
15	9.0 TO 10.0	224	1.052	9.45	95.7	45.71	0.30	3.0	1.43	Y	Y
16	10.0 TO 11.0	167	1.051	10.48	91.3	43.62	0.28	3.3	1.62	Y	Y
17	11.0 TO 12.0	129	1.048	11.45	84.4	40.29	0.27	3.9	1.91	Y	Y
18	12.0 TO 13.0	71	1.053	12.50	73.4	35.00	0.28	5.1	2.62	Y	Y
19	13.0 TO 14.0	66	1.055	13.47	61.7	29.27	0.30	6.0	3.15	Y	Y
20	14.0 TO 15.0	72	1.054	14.43	50.2	23.71	0.26	7.1	3.52	Y	Y
21	15.0 TO 16.0	54	1.063	15.47	35.4	16.67	0.30	6.2	3.00	Y	Y
22	16.0 TO 17.0	22	1.067	16.36	24.8	11.65	0.31	4.5	2.10	Y	Y
23	17.0 TO 18.0	12	1.061	17.48	14.9	6.95	0.28	4.4	1.94	N	N
24	18.0 TO 19.0	12	1.073	18.58	10.5	4.91	0.29	3.1	1.46	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 6544
AVERAGE TEMPERATURE
DURING THE TEST: 287.9 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.25 KPA

AERMOTOR

MANUFACTURER and DISTRIBUTOR:

Tensigrity Systems Limited
RR1
Metcalfe, Ontario, Canada
K0A 2P0
(613) 821-4420

PERFORMANCE:

Testing Period: 249 days
Period Operational:249 days
Percent Availability:100 %

INSTALLED: June 18,1992

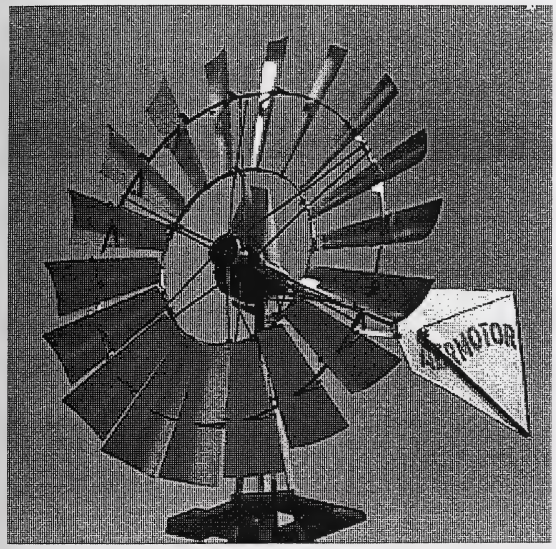

FIGURE 1. Aermotor Wind Turbine.

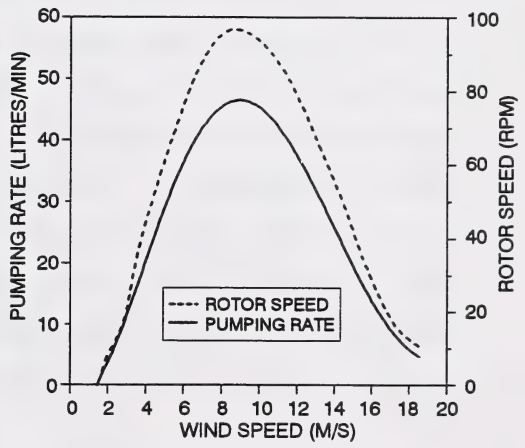

FIGURE 2. Pumping Rate and Rotor Speed versus Wind Speed for an 18 foot (5.5m) Lift.

PHYSICAL DESCRIPTION:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 8 ft (2.44 m)
Swept Area: 50.27 ft² (4.68 m²)
Number of Blades: 18
Blade Design: torque aerofoil
Blade Material: galvanized steel
Hub Height: 25 ft (7.63 m)
Transmission: mechanical gearing
Gear Ratio: 3.29:1
Pump Type: reciprocating piston
Pump Size: 4 in dia. (102 mm)
Stroke: 7.3 in. (18.5 cm)
Pumping System Description:
reciprocating rod connected to positive displacement pump.

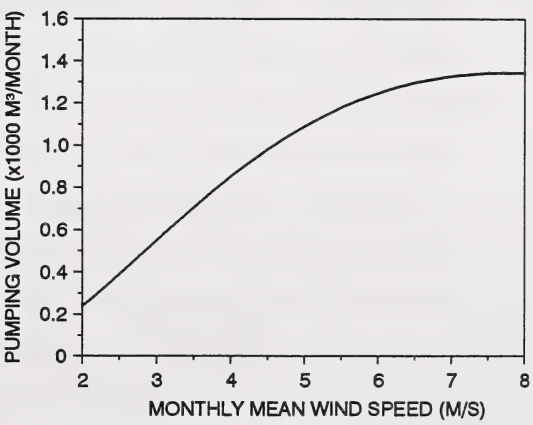

FIGURE 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

ALBERTA RENEWABLE ENERGY TEST SITE
1993 TEST RESULTS OF THE
DUTCH DELTA 16A

The Dutch wind turbine is a direct drive water pumping wind turbine. The unit has a rotor ameter of 4.9 m and is equipped with what has been termed as a perimeter-bladed rotor. This tor is a special low-speed version of the delta-wing rotor developed at the University of Calgary. he objective of this design is to achieve maximum torque at cut-in and limit the rotor speed such at it may be directly coupled to a reciprocating pump. To further improve its cut-in wind speed pabilities, the Delta 16A utilizes a counter-balance mechanism. The mechanism requires the rbine to lift a weight equal to half the weight of the water and sucker rod when the pump is on the wn stroke. During the pump up stroke, this counter-balance then offsets half the weight of the ater and sucker rod. The tower is also unique, as it allows the head, rotor and tail to be assembled ar ground level prior to being slid up the inclined tower side. The entire assembly can be slid up e side of the tower by means of a hand winch.

The unit installed at ARETS has been design for deep well conditions. For 1993 the unit was sted at a lift of 30 metres. There were some initial problems caused by improper set-up of the tail kage. The tail was installed too low resulting in it missing the furling stop and getting stuck in e furled position. There were also some initial problems with the set up of the down hole pump. bottom poppet (valve) stop was set too high which allowed the poppet to extend past the end of e guides and then come to rest on the top of the poppet guides. The last problem which occurred th this system in 1993 was the result of material optimization tests Dutch were conducting. In der to keep the material weight at the top of the tower as light as possible, Dutch had installed a il which was not strong enough to resist the bending forces in the Pincher Creek environment. ese problems were all rectified during the test season, and the results of testing performed after e machine modifications are shown on the specification sheet.

METHOD OF BIN RESULTS FOR: DUTCH DELTA 16A
PUMPING AGAINST A 30 METRE HEAD

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--- BIN SAMPLE AVERAGE ---- AIR DENSITY KG/M^3	WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS ROTOR SPEED	FLOW RATE
1	1.5 TO 2.0	7	1.102	1.60	1.3	1.46	0.27	1.2	1.33	N	N
2	2.0 TO 2.5	8	1.080	2.21	1.2	1.28	0.11	1.1	1.28	N	N
3	2.5 TO 3.0	18	1.083	2.77	3.0	3.47	0.12	2.0	2.38	N	N
4	3.0 TO 3.5	53	1.091	3.27	3.3	3.67	0.13	2.1	2.43	Y	Y
5	3.5 TO 4.0	76	1.090	3.75	7.4	8.70	0.15	3.1	3.83	Y	Y
6	4.0 TO 4.5	86	1.093	4.26	11.8	13.92	0.14	4.3	5.30	N	Y
7	4.5 TO 5.0	133	1.091	4.75	15.8	18.60	0.14	2.8	3.61	Y	Y
8	5.0 TO 5.5	126	1.089	5.26	19.4	23.33	0.15	1.9	2.76	Y	Y
9	5.5 TO 6.0	133	1.086	5.77	23.0	28.54	0.14	1.5	2.32	Y	Y
10	6.0 TO 6.5	147	1.082	6.25	25.9	32.65	0.14	1.5	2.23	Y	Y
11	6.5 TO 7.0	189	1.081	6.76	28.9	37.23	0.14	1.3	1.91	Y	Y
12	7.0 TO 7.5	133	1.080	7.24	31.4	40.89	0.14	1.2	2.03	Y	Y
13	7.5 TO 8.0	134	1.085	7.73	34.1	45.39	0.14	1.1	1.96	Y	Y
14	8.0 TO 9.0	133	1.079	8.39	37.5	51.51	0.28	1.8	3.55	Y	Y
15	9.0 TO 10.0	53	1.068	9.45	39.5	57.12	0.29	3.8	6.27	Y	Y
16	10.0 TO 11.0	44	1.051	10.48	29.5	42.32	0.28	6.6	10.40	Y	N
17	11.0 TO 12.0	34	1.047	11.48	16.9	22.83	0.29	6.8	10.48	N	N
18	12.0 TO 13.0	25	1.049	12.54	9.4	11.36	0.29	3.0	4.58	N	N
19	13.0 TO 14.0	20	1.046	13.49	7.6	8.47	0.32	2.4	3.65	N	N
20	14.0 TO 15.0	22	1.034	14.46	7.0	7.63	0.32	1.3	1.87	N	N
21	15.0 TO 16.0	7	1.049	15.45	8.1	9.13	0.21	0.5	0.68	N	N
22	16.0 TO 17.0	4	1.044	16.44	8.9	10.49	0.26	0.6	0.77	N	N
23	17.0 TO 18.0	5	1.048	17.29	10.2	12.25	0.24	0.3	0.52	N	N
24	18.0 TO 19.0	2	1.049	18.28	10.8	13.05	0.24	0.1	0.18	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 1593
AVERAGE TEMPERATURE
DURING THE TEST: 284.7 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.26 KPA

DELTA 16A (30 Metre Lift)

MANUFACTURER and DISTRIBUTOR:

Dutch Industries Ltd.
705 - 1st Avenue
Regina, Sask., Canada
S4N 4M4
(306) 949-9522

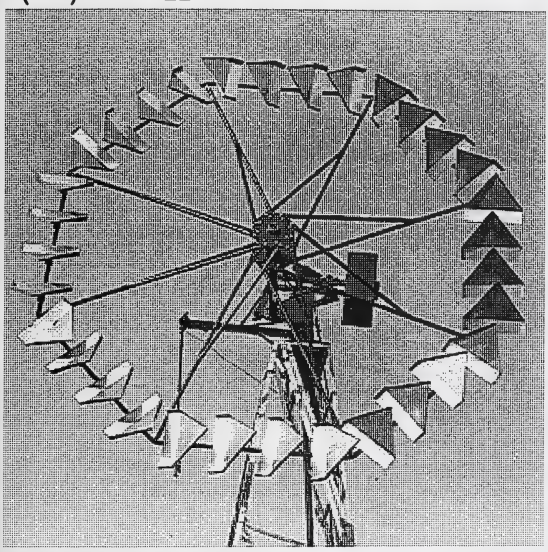

FIGURE 1. DELTA 16A Wind Turbine.

PHYSICAL DESCRIPTION:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 15.8 ft. (4.82 m)
Swept Area: 80.5 ft² (7.48 m²)
Number of Blades: 32
Blade Design: Delta Wing
Blade Material: mild steel (20 GA)
Hub Height: 27 ft. (8.25 m)
Transmission: direct drive
Gear Ratio: 1:1
Pump Type: reciprocating piston
Pump Size: 4 in. dia. (101.6 mm)
Stroke: 6.5 in. (165 mm)
Pumping System Description:
reciprocating rod connected to positive displacement pump

PERFORMANCE:

Testing Period: 143 days
Period Operational: 125 days
Percent Availability: 87 %

INSTALLED: October 1, 1992

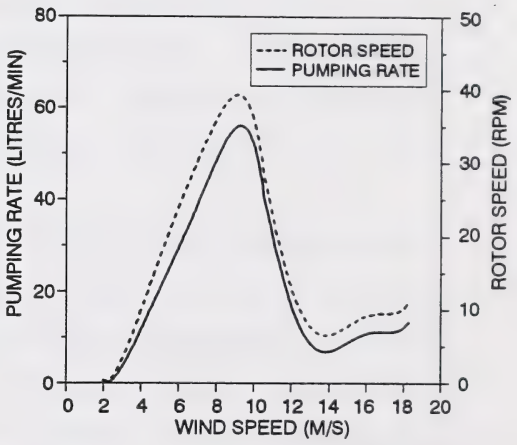

FIGURE 2. Pumping Rate and Rotor Speed versus Wind Speed for a 98 foot (30 m) Lift.

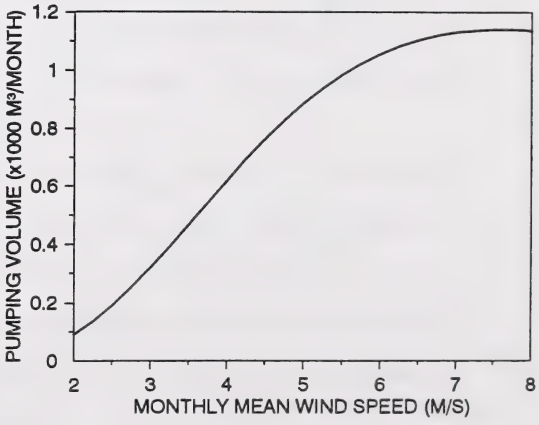

FIGURE 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

ALBERTA RENEWABLE ENERGY TEST SITE
1993 TEST RESULTS OF THE
BREEZE 1

The Breeze 1 wind turbine is manufactured by Wind Powered Equipment of Manning, Alberta. It is a high speed 3-bladed wind turbine designed for aeration applications. The unit operates a diaphragm pump connected directly to the rotor at the rotor head. The turbine is designed to furl out of the wind by pivoting on a horizontal axis such that the rotor "leans back" from the wind to a point at which it is nearly parallel to the wind flow.

The 1993 test season marked the first year of testing at ARETS. It was installed on May 31 and ran well until a support stake was pulled from the ground (due to wind force) causing the machine to fall on June 22. The unit required new blades and these were provided on August 16. Unfortunately, these blades displayed tremendous vibration so the turbine was shut down again until September 14, at which time new blades were installed. As a result of this sequence of false start repairs, the wind turbine was operational for only 34% of the testing period. During the operational periods, ARETS tested this turbine at both 1.5 metre and 3.0 metre submergence. The specification sheets show that the change in submergence affected both the cut-in and the operating performance. At the low submergence level, the unit began aerating at approximately 1.3 m/s, but this value increased to 2.0 m/s when the submergence was increased to 3.0 metres.

ARETS has an ongoing research project into determining how the performance of aerators can best be quantified. For 1993, ARETS introduces in the aerator's specification sheets the amount of air which would be expected to be pumped during a month for various average wind speeds. The application of these results in determining the size of dug out which this unit could maintain its water quality would be very site specific, but this should provide the agricultural specialist with a starting point for assessing the various wind powered aeration systems.

METHOD OF BIN RESULTS FOR: BREEZE AERATOR INJECTING AIR AT 1.5 METRE SUBMERGENCE

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--BIN SAMPLE AVERAGE-- AIR DENSITY KG/M^3	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	2	1.058	1.78	3.68	0.03	0.00	N
2	2.0 TO 2.5	10	1.054	2.35	6.03	0.10	2.10	N
3	2.5 TO 3.0	36	1.063	2.79	9.43	0.14	3.34	N
4	3.0 TO 3.5	64	1.065	3.28	10.83	0.15	3.69	Y
5	3.5 TO 4.0	82	1.061	3.77	14.60	0.15	3.85	Y
6	4.0 TO 4.5	95	1.066	4.24	16.39	0.15	3.22	Y
7	4.5 TO 5.0	91	1.073	4.75	17.90	0.14	2.56	Y
8	5.0 TO 5.5	113	1.070	5.26	20.05	0.13	2.36	Y
9	5.5 TO 6.0	140	1.075	5.73	22.21	0.14	2.02	Y
10	6.0 TO 6.5	106	1.074	6.22	24.33	0.14	2.05	Y
11	6.5 TO 7.0	93	1.069	6.76	26.46	0.14	1.75	Y
12	7.0 TO 7.5	63	1.064	7.24	27.83	0.14	1.60	Y
13	7.5 TO 8.0	79	1.061	7.76	28.73	0.14	1.52	Y
14	8.0 TO 9.0	106	1.063	8.47	31.33	0.26	1.72	Y
15	9.0 TO 10.0	56	1.070	9.44	33.60	0.26	1.68	Y
16	10.0 TO 11.0	27	1.081	10.45	36.83	0.30	1.45	Y
17	11.0 TO 12.0	18	1.081	11.48	38.67	0.29	1.03	Y
18	12.0 TO 13.0	8	1.068	12.63	40.07	0.29	0.43	N
19	13.0 TO 14.0	8	1.070	13.43	41.59	0.31	1.17	N
20	14.0 TO 15.0	2	1.067	14.63	43.60	0.13	0.28	N
21	15.0 TO 16.0	-	-	-	-	-	-	N
22	16.0 TO 17.0	-	-	-	-	-	-	N
23	17.0 TO 18.0	-	-	-	-	-	-	N
24	18.0 TO 19.0	-	-	-	-	-	-	N

TOTAL NUMBER OF
REDUCED DATA SETS: 1202
AVERAGE TEMPERATURE
DURING THE TEST: 287.9 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.22 KPA

METHOD OF BIN RESULTS FOR: BREEZE AERATOR INJECTING AIR AT 3.0 METRE SUBMERGENCE

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--BIN SAMPLE AVERAGE-- AIR DENSITY KG/M^3	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	3	1.093	1.83	0.47	0.11	0.17	N
2	2.0 TO 2.5	5	1.083	2.30	0.78	0.12	0.52	N
3	2.5 TO 3.0	15	1.100	2.78	2.41	0.16	1.60	N
4	3.0 TO 3.5	22	1.094	3.24	5.97	0.14	2.79	N
5	3.5 TO 4.0	30	1.099	3.74	10.26	0.14	1.73	Y
6	4.0 TO 4.5	25	1.089	4.24	11.99	0.14	1.67	Y
7	4.5 TO 5.0	63	1.096	4.77	13.29	0.12	1.72	Y
8	5.0 TO 5.5	66	1.091	5.24	14.55	0.14	1.31	Y
9	5.5 TO 6.0	84	1.090	5.74	16.30	0.14	1.13	Y
10	6.0 TO 6.5	105	1.084	6.25	18.02	0.13	0.99	Y
11	6.5 TO 7.0	143	1.081	6.74	19.03	0.13	0.94	Y
12	7.0 TO 7.5	94	1.084	7.22	19.94	0.15	0.92	Y
13	7.5 TO 8.0	107	1.089	7.72	20.98	0.15	0.90	Y
14	8.0 TO 9.0	82	1.085	8.43	22.48	0.29	0.88	Y
15	9.0 TO 10.0	33	1.069	9.45	24.68	0.25	0.72	Y
16	10.0 TO 11.0	35	1.055	10.50	26.09	0.29	0.58	Y
17	11.0 TO 12.0	20	1.052	11.45	27.66	0.26	0.60	Y
18	12.0 TO 13.0	14	1.050	12.54	28.64	0.30	0.53	Y
19	13.0 TO 14.0	8	1.051	13.57	30.09	0.17	0.31	N
20	14.0 TO 15.0	-	-	-	-	-	-	N
21	15.0 TO 16.0	-	-	-	-	-	-	N
22	16.0 TO 17.0	-	-	-	-	-	-	N
23	17.0 TO 18.0	-	-	-	-	-	-	N
24	18.0 TO 19.0	-	-	-	-	-	-	N

TOTAL NUMBER OF
REDUCED DATA SETS: 956
AVERAGE TEMPERATURE
DURING THE TEST: 283.9 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 88.29 KPA

BREEZE - 1 AERATION TURBINE

MANUFACTURER and DISTRIBUTOR:

Wind Powered Equipment
Box 416
Manning, Alberta, Canada
T0H 2M0
(403) 836-3907
FAX: (403) 836-3022

PERFORMANCE:

Testing Period: 128 days
Period Operational: 44 days
Percent Availability: 34 %

INSTALLED: May 31, 1993

FIGURE 1. BREEZE-1 Aeration Turbine.

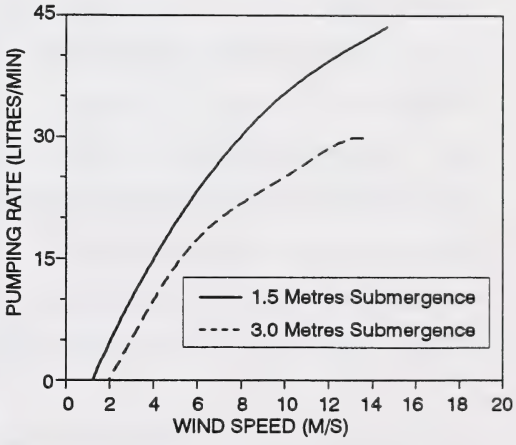

FIGURE 2. Airflow Rate versus Wind Speed for 1.5 M and 3.0 M Submergence

PHYSICAL DESCRIPTION:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 7 ft. (2.13 m)
Swept Area: 38.43 ft² (3.57 m²)
Number of Blades: 3
Blade Design: airfoil
Blade Material: wood
Hub Height: 10.8 ft (3.3 m)
Transmission: direct drive
Gear Ratio: 1:1
Pump Type: diaphragm
Pump Size:diaphragm size = 5.9in (150mm)
Stroke: .7, .86 or .98in (18, 22 or 25mm)
Pumping System Description:
diaphragm pump injects air into water

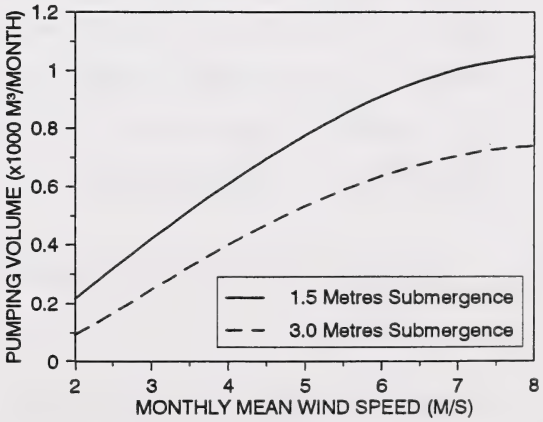

FIGURE 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

ALBERTA RENEWABLE ENERGY TEST SITE
1993 TEST RESULTS OF THE
CANADIAN AGTECHNOLOGY PARTNERS SOLAR SYSTEMS

Canadian Agtechnology Partners tested two photovoltaic pumping systems in 1993. Both systems had been installed during the 1992 test season, but the 1993 configurations utilized revised pump onents. The first system, known as the CAP 348MF5, consisted of three 48 Watt Siemens voltaic panels which were wired in parallel and mounted on a fixed south facing structure. The t of the panels was directed to an "F5" pump. The 1993 version of the F5 had some initial bugs, us was not officially installed until July 28, 1993. Once the installation was complete the pump ithout further problems. This new pump had performance characteristics very nearly identical with revious F5 (tested in 1992). The pump cut-in at approximately 200 W/m^2 and achieved a peak t of 14 L/Minute.

The second system tested during the 1993 season was the CAP 448TRU which consisted of four att Siemens photovoltaic panels which were wired in parallel and mounted on a passive, single axis, ing structure. The output of the panels was directed to a floating centrifugal pump known as the . The system's performance during 1993 was almost identical to that of 1992. The RU system had a cut-in value of 500 W/m^2 which explains the necessity of utilizing a tracking structure. Its peak t of 50 L/Minute is substantially greater than that recorded by the three panel F5 system. This n has demonstrated excellent reliability over its full two year test, indicating that this product has oped to commercial standards.

Further details of these systems can be found on the following performance specification pages.

METHOD OF BIN RESULTS FOR: CAP 3-48-M-F5
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL	# OF DATA SETS	BIN SAMPLE AVERAGE SOLAR RAD.	FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	STANDARD DEVIATION FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	MEET CSA MDBR REQUIREMENTS FLOW RATE	CUR- RENT	VOLT- AGE	POWER
I	M/S	N	KW/M^2	L/M	AMPS	VOLTS	WATTS	L/M	AMPS	VOLTS	WATTS				
1	0.00 TO 0.05	75	0.034	0.00	0.314	0.04	0.01	0.00	0.080	0.01	0.01	Y	Y	Y	Y
2	0.05 TO 0.10	110	0.071	0.00	0.619	0.07	0.05	0.00	0.151	0.02	0.02	Y	Y	Y	Y
3	0.10 TO 0.15	62	0.126	0.00	1.058	0.12	0.13	0.02	0.195	0.03	0.05	Y	Y	Y	Y
4	0.15 TO 0.20	52	0.171	0.02	1.444	0.16	0.24	0.13	0.244	0.03	0.08	Y	Y	Y	Y
5	0.20 TO 0.25	45	0.220	0.20	1.826	0.42	0.85	0.44	0.287	0.51	1.12	Y	Y	Y	Y
6	0.25 TO 0.30	38	0.270	0.89	2.195	1.19	2.83	1.04	0.314	1.09	2.78	N	Y	N	N
7	0.30 TO 0.35	39	0.323	2.07	2.682	2.47	6.88	1.61	0.298	1.66	4.96	N	Y	N	N
8	0.35 TO 0.40	40	0.379	4.79	3.268	5.36	17.69	1.65	0.249	1.69	6.17	N	Y	N	Y
9	0.40 TO 0.45	35	0.430	6.44	3.724	7.16	26.76	1.54	0.195	1.52	6.39	N	Y	N	N
10	0.45 TO 0.50	31	0.473	7.96	4.085	8.85	36.14	1.46	0.181	1.40	6.03	Y	Y	Y	Y
11	0.50 TO 0.55	32	0.522	9.63	4.518	10.69	48.34	1.32	0.167	1.24	6.27	Y	Y	Y	Y
12	0.55 TO 0.60	32	0.573	11.20	4.861	12.42	60.45	1.11	0.172	1.04	6.18	Y	Y	Y	Y
13	0.60 TO 0.65	28	0.622	12.45	5.117	13.86	71.01	0.97	0.176	0.96	6.10	Y	Y	Y	Y
14	0.65 TO 0.70	34	0.675	13.22	5.296	14.92	79.03	0.59	0.125	0.57	3.77	Y	Y	Y	Y
15	0.70 TO 0.75	39	0.723	13.64	5.415	15.50	83.98	0.46	0.139	0.49	3.96	Y	Y	Y	Y
16	0.75 TO 0.80	30	0.775	14.11	5.450	16.09	87.73	0.26	0.142	0.24	2.91	Y	Y	Y	Y
17	0.80 TO 0.85	31	0.824	14.28	5.527	16.38	90.55	0.31	0.124	0.36	3.11	Y	Y	Y	Y
18	0.85 TO 0.90	36	0.876	14.41	5.522	16.55	91.46	0.39	0.139	0.46	4.38	Y	Y	Y	Y
19	0.90 TO 0.95	39	0.927	14.53	5.571	16.77	93.43	0.35	0.124	0.38	3.46	Y	Y	Y	Y
20	0.95 TO 1.00	46	0.979	14.58	5.554	16.82	93.42	0.35	0.120	0.40	3.50	Y	Y	Y	Y
21	1.00 TO 1.10	123	1.056	14.71	5.564	16.95	94.34	0.31	0.106	0.42	3.57	Y	Y	Y	Y
22	1.10 TO 1.20	49	1.119	14.90	5.668	17.02	96.48	0.26	0.109	0.38	3.20	Y	Y	Y	Y
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	N	N	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 1046
AVERAGE TEMPERATURE
DURING THE TEST: 288.0 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 5.42 M/S

METHOD OF BIN RESULTS FOR: CAP 4-48-T-RU

PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL	# OF DATA SETS	BIN SAMPLE AVERAGE SOLAR RAD.	FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	STANDARD DEVIATION FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	MEET CSA MDBR REQUIREMENTS FLOW RATE	CUR- RENT	VOLT- AGE	POWER
I	M/S	N	KW/M^2	L/M	AMPS	VOLTS	WATTS	L/M	AMPS	VOLTS	WATTS	RATE	RENT	AGE	POWER
1	0.00 TO 0.05	-	-	-	-	-	-	-	-	-	-	N	N	N	N
2	0.05 TO 0.10	1103	0.075	0.00	0.925	0.17	0.18	0.00	0.176	0.24	0.28	Y	Y	Y	Y
3	0.10 TO 0.15	627	0.124	0.00	1.500	1.76	2.78	0.01	0.184	1.12	1.95	Y	Y	Y	Y
4	0.15 TO 0.20	488	0.174	0.00	2.046	4.03	8.36	0.04	0.189	1.01	2.54	Y	Y	Y	Y
5	0.20 TO 0.25	403	0.223	0.05	2.595	5.74	15.01	0.33	0.201	0.93	3.22	Y	Y	Y	Y
6	0.25 TO 0.30	305	0.273	0.12	3.156	7.16	22.71	0.60	0.215	0.96	4.07	Y	Y	Y	Y
7	0.30 TO 0.35	226	0.323	0.51	3.735	8.43	31.63	1.38	0.233	0.97	4.95	Y	Y	Y	Y
8	0.35 TO 0.40	226	0.374	0.89	4.311	9.43	40.76	1.96	0.223	0.90	5.12	Y	Y	Y	Y
9	0.40 TO 0.45	195	0.425	1.91	4.870	10.53	51.40	2.89	0.259	0.99	6.62	Y	Y	Y	Y
10	0.45 TO 0.50	226	0.475	3.56	5.431	11.18	60.88	3.62	0.267	1.01	7.35	Y	Y	Y	Y
11	0.50 TO 0.55	186	0.526	6.92	6.031	11.82	71.42	4.79	0.288	0.94	7.77	Y	Y	Y	Y
12	0.55 TO 0.60	214	0.576	10.18	6.583	12.32	81.17	4.56	0.287	0.86	7.80	Y	Y	Y	Y
13	0.60 TO 0.65	233	0.625	14.51	7.129	12.71	90.70	4.32	0.268	0.73	7.36	Y	Y	Y	Y
14	0.65 TO 0.70	222	0.677	18.75	7.711	13.04	100.61	3.98	0.289	0.66	7.45	Y	Y	Y	Y
15	0.70 TO 0.75	258	0.726	23.00	8.272	13.35	110.50	4.01	0.284	0.68	8.06	Y	Y	Y	Y
16	0.75 TO 0.80	266	0.776	27.22	8.812	13.70	120.75	3.69	0.273	0.59	7.57	Y	Y	Y	Y
17	0.80 TO 0.85	320	0.826	31.14	9.286	13.95	129.58	3.47	0.315	0.56	7.85	Y	Y	Y	Y
18	0.85 TO 0.90	345	0.876	35.17	9.793	14.27	139.77	3.30	0.284	0.51	7.09	Y	Y	Y	Y
19	0.90 TO 0.95	371	0.926	38.16	10.207	14.47	147.69	3.18	0.309	0.47	6.85	Y	Y	Y	Y
20	0.95 TO 1.00	517	0.978	41.46	10.649	14.69	156.39	3.08	0.304	0.42	5.70	Y	Y	Y	Y
21	1.00 TO 1.10	1353	1.042	45.23	11.044	14.95	165.05	3.92	0.342	0.46	7.30	Y	Y	Y	Y
22	1.10 TO 1.20	89	1.122	51.18	11.564	15.29	176.78	3.26	0.347	0.27	5.23	Y	Y	Y	Y
23	1.20 TO 1.30	2	1.210	52.13	12.080	15.16	183.19	0.56	0.030	0.06	1.12	N	N	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 8175
AVERAGE TEMPERATURE
DURING THE TEST: 291.2 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 4.74 M/S

CAP 348MF5

MANUFACTURER AND DISTRIBUTOR:

Canadian
Agtechnology Partners
P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0
(403) 556-8779

PERFORMANCE:

Testing Period: 178 days
Period Operational:153 days
Percent Availability:86 %

INSTALLED: June 26, 1992

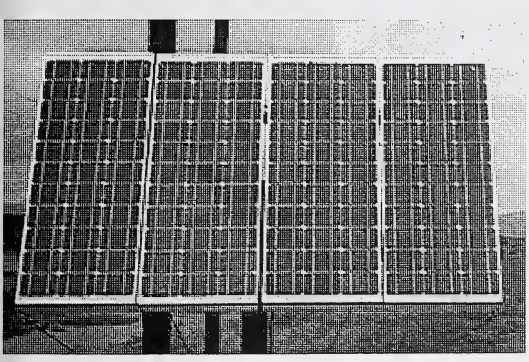

FIGURE 1. CAP 348MF5 Solar System.

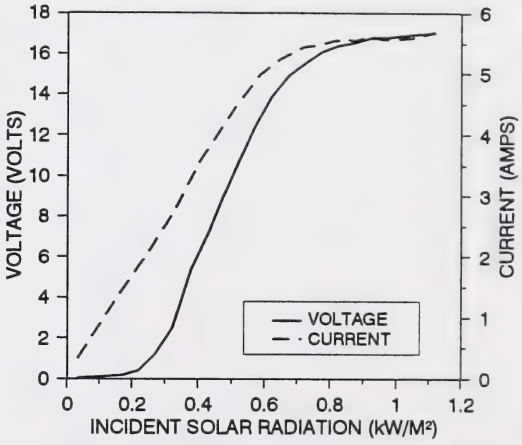

FIGURE 2. Voltage and Current versus Incident Solar Radiation for an 18 foot (5.5 m) Lift.

PHYSICAL DESCRIPTION:

Number of Panels: 3
Panel Manufacturer: Siemens
Power Rating @ 77°F (25 C) and 93 W/ft²-
(1000 W/m²) : 48 W/panel
Configuration: Parallel
Mount: fixed
Pump Type: diaphragm submersible pump (F5)

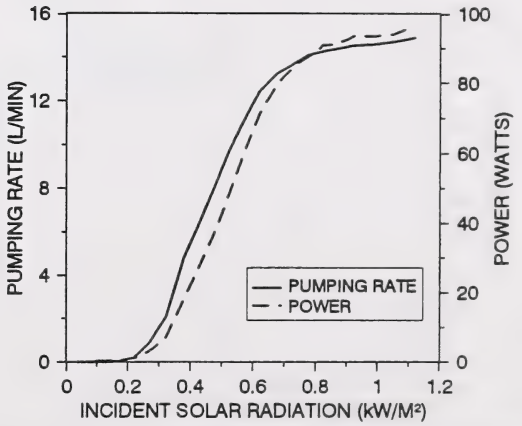

FIGURE 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 foot (5.5 m) Lift.

CAP 448TRU

MANUFACTURER AND DISTRIBUTOR:

Canadian
Agtechnology Partners
P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0
(403) 556-8779

PERFORMANCE:

Testing Period: 188 days
Period Operational: 188 days
Percent Availability: 100 %

INSTALLED: August 31, 1992

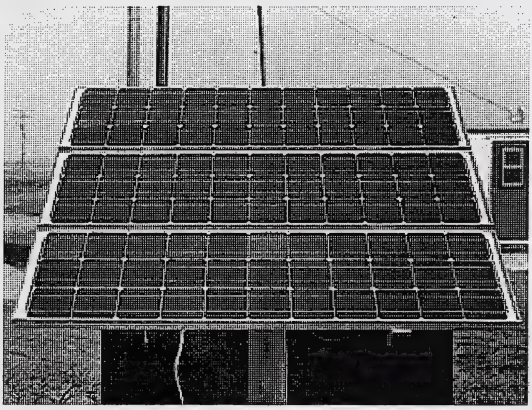

FIGURE 1. CAP 448TRU Solar System.

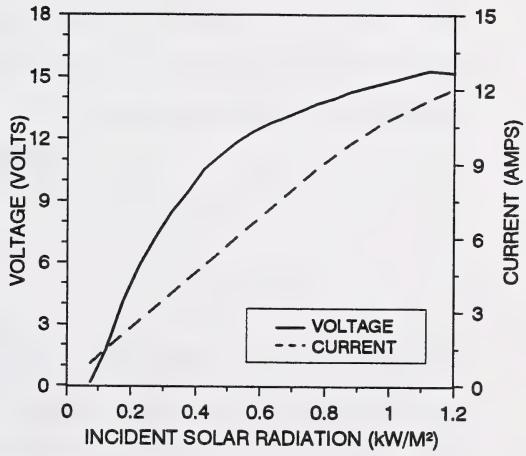

FIGURE 2. Voltage and Current versus Incident Solar Radiation for an 18 foot (5.5 m) Lift.

PHYSICAL DESCRIPTION:

Number of Panels: 4
Panel Manufacturer: Siemens
Power Rating @ 77°F (25 C) and 93 W/ft²-
(1000 W/m²) : 48 W/panel
Configuration: Parallel
Mount: tracker
Pump Type: floating centrifugal (RU)

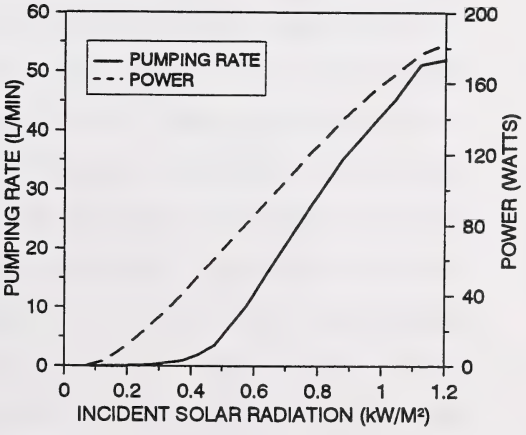

FIGURE 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 foot (5.5 m) Lift.

ALBERTA RENEWABLE ENERGY TEST SITE
1993 TEST RESULTS OF THE
KELLN CONSULTING LTD. SOLAR SYSTEMS

This was the first year of testing at the Alberta Renewable Energy Test Site for Kelln Consulting Ltd. Kelln, located in Lumsden, Saskatchewan, is a manufacturer/distributor of photovoltaic systems for a wide variety of applications. The company installed two systems at ARETS, and for each system, two configurations were tested.

WATER PUMPING SYSTEM

The water pumping systems consisted of six 22 Watt United Solar Systems Corporation photovoltaic panels wired in parallel. The output of these panels were regulated by an LCB and subsequently directed to a rotary vane pump. Two configurations of this system was tested. The first configuration had the panels separated in groups of three, with each group offset from due South by approximately 40 degrees (azimuth). The theory behind this is that the pump is sufficiently undersized to require the output of only one set of panels. By offsetting the panels, the daily operating period extends over a greater time frame (the rising sun shines almost directly on one set of panels, as does the setting sun). To monitor this system, pyranometers were required on both sets of panels. The average of these two sensors would represent the average solar intensity on the system. The results indicate the low "average" solar intensity required to start the system (approximately 50 W/m^2). Obviously, this average is made up of one set of panels receiving much greater solar incidence than the other. To determine if this is the real cut-in of the system, and to determine what other effects the bi-directional installation would have on the system performance, the system was also tested with all six panels facing South. The results confirm the cut-in solar radiation intensity is between 50 and 75 W/m^2. The graphs also show that the split system had no significant effect on the performance curve. However, the true measure

of this systems' performance would be a determination of the difference in operating hours between the south and the bi-directional systems. This type of calculation is planned to be undertaken during the 1994 test season.

WATER AERATION SYSTEM

The second system that Kelln installed at ARETS during 1993 was a single panel aeration system. The system consisted of a single 62.7 Watt Kyocera Corporation photovoltaic panel supplying power to a 12 volt D.C. piston air compressor. The system was tested at injection submergence levels of 1.5 and 3.0 metres. The results found only a marginal drop in air injection rate for the increased depth. In either test, at full sunlight, the system would provide approximately 15 L/Minute of air. As well, the output curves are nearly linear, with cut-in occurring at approximately 200 W/m^2.

As was mentioned previously, ARETS has an ongoing research project into determining how the performance of aerators can best be quantified. This quantification is further complicated by the lack of an industry standard method from reporting expected monthly yields from solar systems. These as yet determined quantification procedures are required to determine the size of dug out which this unit could maintain its water quality.

Further details of both systems and their respective configuration tests can be found on the following performance specification pages.

METHOD OF BIN RESULTS FOR: KELLN SW/SE FACING WATER PUMPER PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL	# OF DATA SETS	BIN SAMPLE AVERAGE SOLAR RAD.	FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	STANDARD DEVIATION ----- FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	MEET CSA MDBR ---- REQUIREMENTS ----- FLOW RATE	CUR-RENT	VOLT-AGE	POWER
I	M/S	N	KW/M^2	L/M	AMPS	VOLTS	WATTS	L/M	AMPS	VOLTS	WATTS				
1	0.00 TO 0.05	293	0.036	0.00	2.224	1.05	2.49	0.00	0.655	0.32	1.49	Y	Y	Y	Y
2	0.05 TO 0.10	456	0.074	0.35	3.611	2.13	7.73	1.12	0.748	1.44	4.98	Y	Y	Y	Y
3	0.10 TO 0.15	251	0.122	0.78	4.431	2.95	12.14	1.54	0.745	1.83	5.04	Y	Y	Y	Y
4	0.15 TO 0.20	181	0.173	1.76	4.448	4.19	16.42	1.87	1.217	2.11	4.43	Y	Y	Y	Y
5	0.20 TO 0.25	138	0.226	3.93	3.509	6.77	22.57	1.44	0.907	1.64	3.44	Y	Y	Y	Y
6	0.25 TO 0.30	114	0.272	5.42	3.148	8.63	26.98	0.77	0.322	0.93	2.17	Y	Y	Y	Y
7	0.30 TO 0.35	83	0.326	6.43	3.134	9.93	31.10	0.77	0.163	1.09	3.71	Y	Y	Y	Y
8	0.35 TO 0.40	86	0.375	7.30	3.134	11.03	34.68	0.99	0.149	1.37	5.44	Y	Y	Y	Y
9	0.40 TO 0.45	84	0.427	8.35	3.161	12.42	39.45	1.43	0.142	2.01	7.57	Y	Y	Y	Y
10	0.45 TO 0.50	87	0.475	9.44	3.227	13.88	45.03	1.43	0.143	2.10	8.23	Y	Y	Y	Y
11	0.50 TO 0.55	78	0.525	10.07	3.280	14.69	48.37	1.37	0.136	1.89	7.66	Y	Y	Y	Y
12	0.55 TO 0.60	74	0.575	10.78	3.316	15.62	51.94	1.14	0.126	1.57	6.42	Y	Y	Y	Y
13	0.60 TO 0.65	63	0.624	11.40	3.344	16.37	54.83	0.96	0.117	1.34	5.74	Y	Y	Y	Y
14	0.65 TO 0.70	73	0.676	11.72	3.383	16.83	56.99	0.74	0.101	1.01	4.59	Y	Y	Y	Y
15	0.70 TO 0.75	64	0.724	11.92	3.374	17.07	57.64	0.69	0.100	0.90	4.03	Y	Y	Y	Y
16	0.75 TO 0.80	69	0.774	12.16	3.375	17.33	58.56	0.61	0.108	0.85	4.25	Y	Y	Y	Y
17	0.80 TO 0.85	66	0.827	12.41	3.383	17.65	59.72	0.48	0.097	0.64	3.25	Y	Y	Y	Y
18	0.85 TO 0.90	68	0.876	12.53	3.383	17.78	60.16	0.45	0.100	0.64	3.29	Y	Y	Y	Y
19	0.90 TO 0.95	76	0.923	12.70	3.397	18.08	61.46	0.35	0.103	0.55	3.21	Y	Y	Y	Y
20	0.95 TO 1.00	57	0.976	12.88	3.396	18.21	61.86	0.25	0.094	0.39	2.70	Y	Y	Y	Y
21	1.00 TO 1.10	172	1.051	12.99	3.387	18.36	62.21	0.19	0.087	0.42	2.68	Y	Y	Y	Y
22	1.10 TO 1.20	80	1.133	13.15	3.396	18.65	63.33	0.16	0.078	0.36	2.01	Y	Y	Y	Y
23	1.20 TO 1.30	2	1.215	13.05	3.365	18.69	62.88	0.01	0.035	0.34	0.49	N	N	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 2715
AVERAGE TEMPERATURE
DURING THE TEST: 290.7 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 4.51 M/S

METHOD OF BIN RESULTS FOR: KELLN SOUTH FACING WATER PUMPER PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL	# OF DATA SETS	BIN SAMPLE AVERAGE SOLAR RAD.	FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	---- STANDARD DEVIATION ----- FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	---- MEET CSA MDBR ---- REQUIREMENTS ----- FLOW	CUR-	VOLT-	
I	M/S	N	KW/M^2	L/M	AMPS	VOLTS	WATTS	L/M	AMPS	VOLTS	WATTS	RATE	RENT	AGE	POWER
1	0.00 TO 0.05	182	0.036	0.00	1.965	1.07	2.17	0.00	0.418	0.25	0.85	Y	Y	Y	Y
2	0.05 TO 0.10	259	0.073	0.02	3.193	1.67	5.44	0.22	0.510	0.40	1.99	Y	Y	Y	Y
3	0.10 TO 0.15	138	0.123	0.62	3.828	2.64	9.95	0.80	0.512	1.02	3.46	Y	Y	Y	Y
4	0.15 TO 0.20	111	0.173	1.77	3.495	4.08	13.94	0.88	0.496	1.19	3.31	Y	Y	Y	Y
5	0.20 TO 0.25	99	0.223	3.39	3.300	6.11	19.97	1.00	0.267	1.31	3.78	Y	Y	Y	Y
6	0.25 TO 0.30	78	0.271	4.64	3.284	7.80	25.47	0.91	0.204	1.28	3.56	Y	Y	Y	Y
7	0.30 TO 0.35	67	0.325	5.84	3.317	9.43	31.12	0.91	0.205	1.43	3.92	Y	Y	Y	Y
8	0.35 TO 0.40	49	0.375	6.32	3.427	10.13	34.62	0.87	0.194	1.25	3.95	Y	Y	Y	Y
9	0.40 TO 0.45	38	0.425	7.13	3.482	11.07	38.55	1.19	0.184	1.59	5.76	Y	Y	Y	Y
10	0.45 TO 0.50	34	0.471	8.43	3.547	12.95	45.88	1.17	0.188	1.51	5.30	Y	Y	Y	Y
11	0.50 TO 0.55	41	0.522	9.31	3.630	14.03	50.88	0.90	0.183	1.15	4.52	Y	Y	Y	Y
12	0.55 TO 0.60	40	0.574	10.15	3.720	15.16	56.32	0.83	0.241	1.02	4.23	Y	Y	Y	Y
13	0.60 TO 0.65	43	0.626	10.55	3.807	15.45	58.76	0.83	0.254	1.21	5.23	Y	Y	Y	Y
14	0.65 TO 0.70	31	0.675	10.93	3.825	15.84	60.58	0.76	0.230	1.63	6.86	Y	Y	Y	Y
15	0.70 TO 0.75	38	0.724	11.34	3.823	16.23	62.03	0.59	0.263	1.29	6.12	Y	Y	Y	Y
16	0.75 TO 0.80	42	0.776	11.68	3.820	16.56	63.15	0.55	0.225	1.45	5.55	Y	Y	Y	Y
17	0.80 TO 0.85	33	0.826	11.94	3.818	17.16	65.53	0.54	0.201	0.91	4.81	Y	Y	Y	Y
18	0.85 TO 0.90	40	0.875	11.98	3.891	16.91	65.67	0.49	0.247	1.53	6.14	Y	Y	Y	Y
19	0.90 TO 0.95	43	0.929	12.16	3.819	16.97	64.69	0.45	0.169	1.62	5.76	Y	Y	Y	Y
20	0.95 TO 1.00	41	0.977	12.33	3.789	17.36	65.80	0.37	0.172	1.38	6.05	Y	Y	Y	Y
21	1.00 TO 1.10	98	1.050	12.57	3.769	17.98	67.72	0.25	0.213	0.51	3.33	Y	Y	Y	Y
22	1.10 TO 1.20	22	1.127	12.58	3.891	17.71	68.82	0.28	0.160	1.09	3.85	Y	Y	Y	Y
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	N	N	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 1567
AVERAGE TEMPERATURE
DURING THE TEST: 290.0 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 3.91 M/S

METHOD OF BIN RESULTS FOR: KELLN AERATOR INJECTING AIR AT 1.5 METRE SUBMERGENCE

BIN NO.	BIN INTERVAL	# OF DATA SETS	B I N S A M P L E A V E R A G E SOLAR RAD.	FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	---- STANDARD DEVIATION ----- FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	---- MEET CSA MDBR ---- REQUIREMENTS ----- FLOW RATE	CUR-RENT	VOLT-AGE	POWER
I	M/S	N	KW/M^2	L/M	AMPS	VOLTS	WATTS	L/M	AMPS	VOLTS	WATTS	RATE	RENT	AGE	POWER
1	0.00 TO 0.05	386	0.036	0.00	1.109	0.78	0.87	0.00	0.236	0.17	0.27	Y	Y	Y	Y
2	0.05 TO 0.10	557	0.072	0.00	1.855	1.16	2.18	0.03	0.414	0.22	0.84	Y	Y	Y	Y
3	0.10 TO 0.15	279	0.122	0.01	2.615	1.42	3.73	0.08	0.363	0.21	0.91	Y	Y	Y	Y
4	0.15 TO 0.20	214	0.174	0.21	3.085	1.68	5.16	0.44	0.321	0.23	0.82	Y	Y	Y	Y
5	0.20 TO 0.25	180	0.225	1.07	3.320	2.13	7.02	0.80	0.320	0.31	0.84	Y	Y	Y	Y
6	0.25 TO 0.30	161	0.273	1.87	3.443	2.58	8.75	0.93	0.415	0.38	0.89	Y	Y	Y	Y
7	0.30 TO 0.35	134	0.324	2.91	3.450	3.10	10.66	0.75	0.247	0.30	0.89	Y	Y	Y	Y
8	0.35 TO 0.40	122	0.374	3.74	3.581	3.53	12.62	0.75	0.239	0.32	1.05	Y	Y	Y	Y
9	0.40 TO 0.45	112	0.427	4.63	3.677	3.98	14.61	0.76	0.192	0.35	1.41	Y	Y	Y	Y
10	0.45 TO 0.50	111	0.474	5.42	3.801	4.40	16.73	0.73	0.164	0.34	1.36	Y	Y	Y	Y
11	0.50 TO 0.55	105	0.524	6.24	3.878	4.86	18.83	0.68	0.147	0.33	1.39	Y	Y	Y	Y
12	0.55 TO 0.60	111	0.577	7.18	3.967	5.35	21.21	0.73	0.146	0.37	1.65	Y	Y	Y	Y
13	0.60 TO 0.65	97	0.626	8.09	4.038	5.84	23.57	0.75	0.124	0.32	1.47	Y	Y	Y	Y
14	0.65 TO 0.70	90	0.675	8.82	4.137	6.23	25.78	0.76	0.123	0.37	1.88	Y	Y	Y	Y
15	0.70 TO 0.75	90	0.724	9.49	4.212	6.56	27.65	0.75	0.104	0.35	1.66	Y	Y	Y	Y
16	0.75 TO 0.80	94	0.774	10.16	4.336	6.94	30.10	0.67	0.094	0.29	1.40	Y	Y	Y	Y
17	0.80 TO 0.85	93	0.827	10.92	4.425	7.34	32.50	0.83	0.111	0.35	1.91	Y	Y	Y	Y
18	0.85 TO 0.90	103	0.875	11.45	4.507	7.60	34.26	0.71	0.120	0.34	1.99	Y	Y	Y	Y
19	0.90 TO 0.95	106	0.925	12.04	4.616	8.00	36.92	0.73	0.095	0.33	1.98	Y	Y	Y	Y
20	0.95 TO 1.00	103	0.975	12.69	4.702	8.38	39.40	0.73	0.095	0.28	1.60	Y	Y	Y	Y
21	1.00 TO 1.10	303	1.054	13.78	4.799	8.95	42.97	0.84	0.103	0.35	1.84	Y	Y	Y	Y
22	1.10 TO 1.20	114	1.131	14.76	4.847	9.48	45.92	0.62	0.108	0.22	1.22	Y	Y	Y	Y
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	N	N	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 3666
AVERAGE TEMPERATURE
DURING THE TEST: 291.4 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 4.38 M/S

METHOD OF BIN RESULTS FOR: KELLN AERATOR INJECTING AIR AT 3.0 METRE SUBMERGENCE

BIN NO.	BIN INTERVAL	# OF DATA SETS	BIN SAMPLE AVERAGE SOLAR RAD.	FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	STANDARD DEVIATION ----- FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	MEET CSA MDBR ---- REQUIREMENTS ----- FLOW	CUR-	VOLT-
I	M/S	N	KW/M^2	L/M	AMPS	VOLTS	WATTS	L/M	AMPS	VOLTS	WATTS	RATE	RENT	AGE POWER
1	0.00 TO 0.05	155	0.035	0.00	1.095	0.61	0.69	0.00	0.230	0.22	0.31	Y	Y	Y Y
2	0.05 TO 0.10	202	0.073	0.00	1.838	0.91	1.70	0.00	0.341	0.25	0.60	Y	Y	Y Y
3	0.10 TO 0.15	127	0.125	0.00	2.553	1.24	3.17	0.02	0.283	0.27	0.76	Y	Y	Y Y
4	0.15 TO 0.20	94	0.171	0.01	3.070	1.43	4.39	0.05	0.358	0.27	0.95	Y	Y	Y Y
5	0.20 TO 0.25	81	0.219	0.31	3.424	1.72	5.85	0.54	0.284	0.31	1.05	Y	Y	Y Y
6	0.25 TO 0.30	70	0.273	1.21	3.524	2.25	7.86	0.97	0.252	0.43	1.26	Y	Y	Y Y
7	0.30 TO 0.35	67	0.325	2.22	3.598	2.76	9.85	1.03	0.307	0.45	1.24	Y	Y	Y Y
8	0.35 TO 0.40	66	0.376	3.20	3.625	3.32	11.99	0.77	0.279	0.40	1.29	Y	Y	Y Y
9	0.40 TO 0.45	59	0.429	4.13	3.708	3.85	14.26	0.76	0.241	0.39	1.48	Y	Y	Y Y
10	0.45 TO 0.50	50	0.473	4.66	3.802	4.20	15.95	0.58	0.151	0.35	1.46	Y	Y	Y Y
11	0.50 TO 0.55	57	0.520	5.43	3.898	4.65	18.13	0.57	0.141	0.36	1.61	Y	Y	Y Y
12	0.55 TO 0.60	51	0.572	6.26	3.991	5.13	20.51	0.49	0.115	0.37	1.77	Y	Y	Y Y
13	0.60 TO 0.65	53	0.624	7.02	4.088	5.59	22.86	0.56	0.109	0.42	1.95	Y	Y	Y Y
14	0.65 TO 0.70	52	0.676	7.95	4.191	6.16	25.83	0.70	0.126	0.47	2.65	Y	Y	Y Y
15	0.70 TO 0.75	61	0.725	8.33	4.260	6.37	27.18	0.75	0.118	0.53	2.74	Y	Y	Y Y
16	0.75 TO 0.80	49	0.775	8.86	4.366	6.74	29.43	0.61	0.081	0.35	1.68	Y	Y	Y Y
17	0.80 TO 0.85	52	0.823	9.46	4.470	7.08	31.63	0.61	0.090	0.37	1.87	Y	Y	Y Y
18	0.85 TO 0.90	57	0.875	9.99	4.560	7.45	33.97	0.43	0.080	0.27	1.46	Y	Y	Y Y
19	0.90 TO 0.95	63	0.926	10.58	4.656	7.81	36.36	0.58	0.105	0.37	2.20	Y	Y	Y Y
20	0.95 TO 1.00	66	0.978	11.13	4.762	8.16	38.88	0.48	0.081	0.28	1.66	Y	Y	Y Y
21	1.00 TO 1.10	227	1.058	12.11	4.906	8.76	42.99	0.62	0.094	0.30	1.91	Y	Y	Y Y
22	1.10 TO 1.20	67	1.121	12.90	4.981	9.21	45.88	0.65	0.096	0.34	1.91	Y	Y	Y Y
23	1.20 TO 1.30	4	1.227	14.29	4.968	9.98	49.61	0.19	0.169	0.07	2.03	N	N	N N

TOTAL NUMBER OF
REDUCED DATA SETS: 1830
AVERAGE TEMPERATURE
DURING THE TEST: 288.8 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 5.21 M/S

KELLN 6-PANEL WATER SYSTEM

MANUFACTURER AND DISTRIBUTOR:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

PERFORMANCE:

Testing Period: 140 days
Period Operational: 140 days
Percent Availability: 100 %

INSTALLED: May 6, 1993

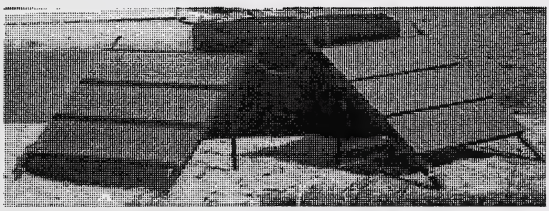

FIGURE 1. Kelln 6-Panel Water System.

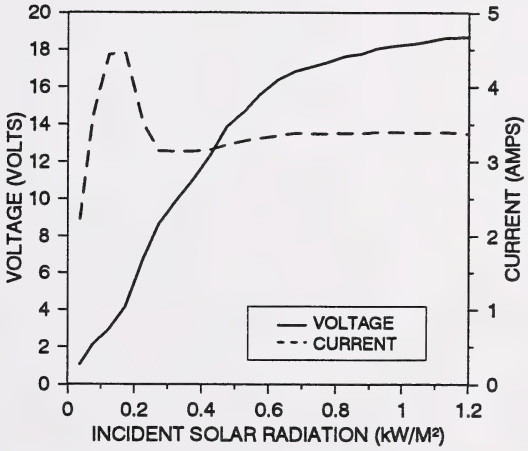

FIGURE 2. Voltage and Current versus Incident Solar Radiation for an 18 foot (5.5m) Lift.

PHYSICAL DESCRIPTION:

Number of Panels: 6
Panel Manufacturer: United Solar Systems Corp.
Maximum Panel Power Output: 22 Watts
Wiring Configuration: Parallel
Mount: fixed, bi-directional (S.E. and S.W.)
LCB: yes, LCB-20 Sun Selector
Pump Type: Rotary vane

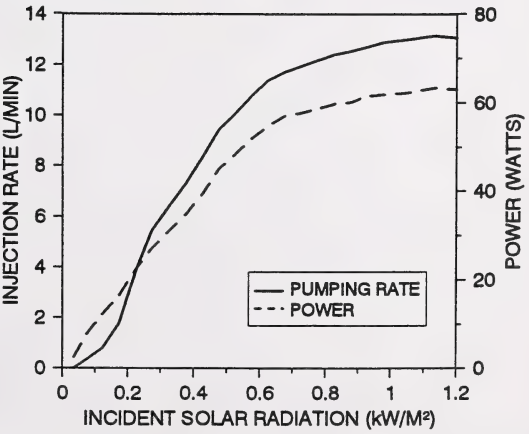

FIGURE 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 foot (5.5m) Lift.

KELLN 6-PANEL WATER SYSTEM

MANUFACTURER AND DISTRIBUTOR:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

PERFORMANCE:

Testing Period: 140 days
Period Operational: 140 days
Percent Availability: 100 %

INSTALLED: May 6, 1993

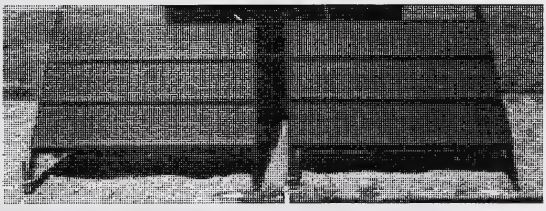

FIGURE 1. Kelln 6-Panel Water System.

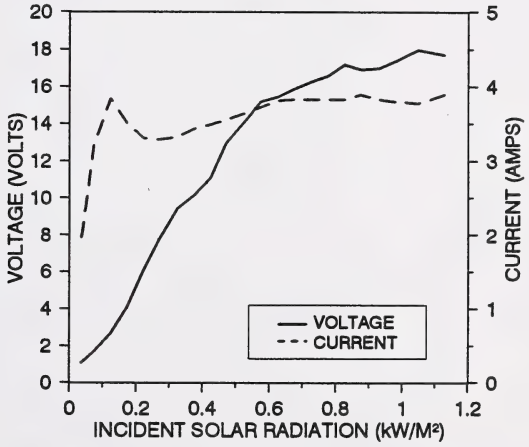

FIGURE 2. Voltage and Current versus Incident Solar Radiation for an 18 foot (5.5m) Lift.

PHYSICAL DESCRIPTION:

Number of Panels: 6
Panel Manufacturer: United Solar Systems Corp.
Maximum Panel Power Output: 22 Watts
Wiring Configuration: Parallel
Mount: fixed, South Facing
LCB: yes, LCB-20 Sun Selector
Pump Type: Rotary vane

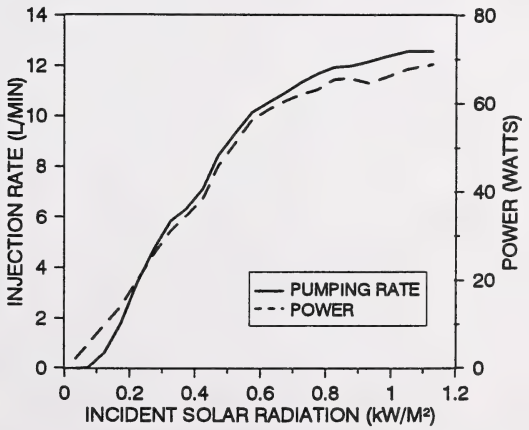

FIGURE 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 foot (5.5m) Lift.

KELLN 1-PANEL AERATION SYSTEM

MANUFACTURER AND DISTRIBUTOR:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

PERFORMANCE:

Testing Period: 104 days
Period Operational: 104 days
Percent Availability: 100 %

INSTALLED: June 18, 1993

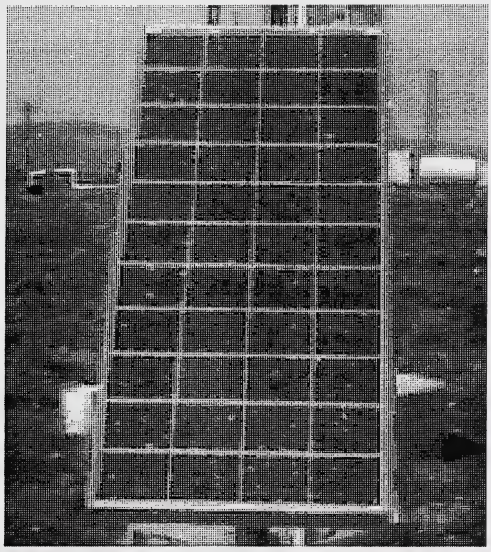

FIGURE 1. Kelln 1-Panel Aeration System.

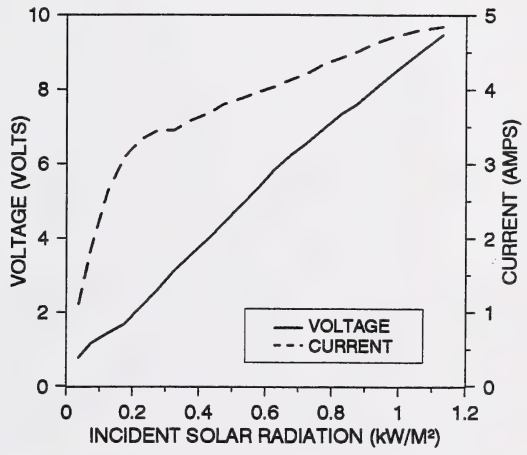

FIGURE 2. Voltage and Current versus Incident Solar Radiation for a 5 foot (1.5m) Submergence.

PHYSICAL DESCRIPTION:

Number of Panels: 1
Panel Manufacturer: Kyocera Corporation
Maximum Panel Power Output: 62.7 Watts
Wiring Configuration: Wired direct to LCB, LCB wired to pump
Mount: fixed
LCB: yes, 3M-T Sun Selector
Pump Type: 12v, piston air compressor

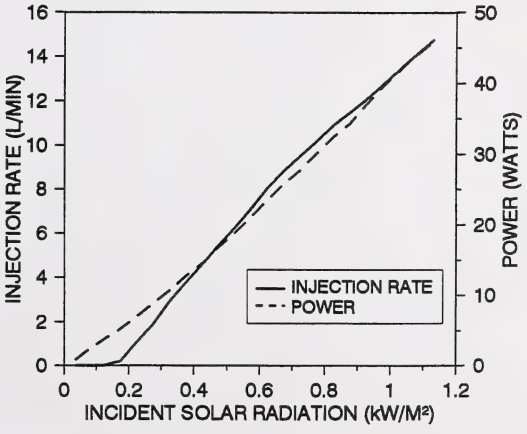

FIGURE 3. Airflow Rate and Power versus Incident Solar Radiation for a 5 foot (1.5m) Submergence.

KELLN 1-PANEL AERATION SYSTEM

MANUFACTURER AND DISTRIBUTOR:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

PERFORMANCE:

Testing Period: 104 days
Period Operational: 104 days
Percent Availability: 100 %

INSTALLED: June 18, 1993

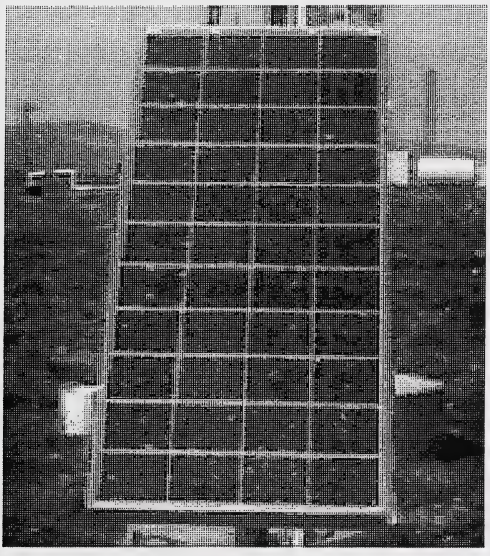

FIGURE 1. Kelln 1-Panel Aeration System.

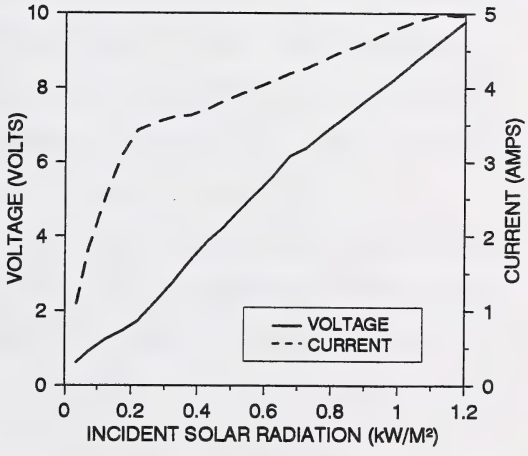

FIGURE 2. Voltage and Current versus Incident Solar Radiation for a 10 foot (3.0m) Submergence.

PHYSICAL DESCRIPTION:

Number of Panels: 1
Panel Manufacturer: Kyocera Corporation
Maximum Panel Power Output: 62.7 Watts
Wiring Configuration: Wired direct to LCB, LCB wired to pump
Mount: fixed
LCB: yes, 3M-T Sun Selector
Pump Type: 12v, piston air compressor

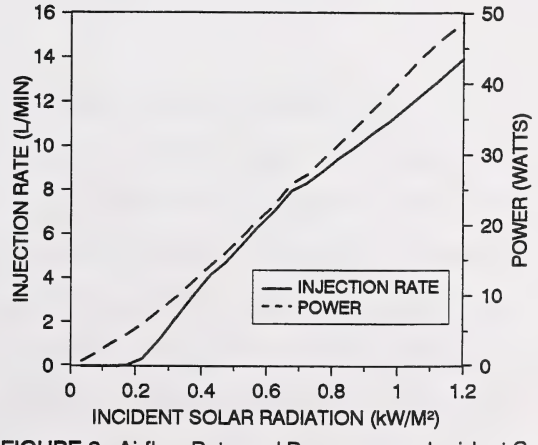

FIGURE 3. Airflow Rate and Power versus Incident Solar Radiation for a 10 foot (3.0m) Submergence.

5.0 OTHER ACTIVITIES AT ARETS

In the spring of 1994, the test site will be undergoing a major revision in its data collection and analysis system. The new system will be based on MicroSoft's Visual Basic 3.0 Professional Edition software with Custom RS-232 Controls. This software is designed such that as data is collected it will be immediately stored in MicroSoft's Access Database software. As both software packages operate within windows, the data will be immediately available to graphing packages. As well, the Query capabilities of the Access Database will allow for data selection and graphing of any parameters for any time period. This will assist manufacturer's "on-site" as they fine tune the performance of their systems.

Also planned for 1994 is the development of standard signage for each system under test. These signs will include information typical of the interpretive displays being generated at the Old Man Dam. It is expected that once the Main Old Man Dam Interpretive Centre is completed, ARETS will become one of the "distributed" interpretive centres in the Pincher Creek area.

6.0 CONCLUSIONS

The Alberta Renewable Energy Test Site evaluated sixteen pumping configurations in 1993. All windmill test sites were filled, although one was used for demonstration only. The centre site (site 4) was designated as the aeration test bed and it serviced two wind turbines and one photovoltaic system. This marked the first year of quantitative performance testing of aeration systems. ARETS developed the test procedure to follow that utilized in testing water pumping systems. The calculation of volume of pumped air per month for various wind regimes represents a first step in developing a sizing methods for wind aeration systems. The high demand for aeration systems as reported to ARETS by the manufacturers indicates that ARETS should continue to pursue this testing, analysis and design procedure. Likewise, this demand will be

further accommodated by ARETS in 1994 by presenting a seminar on water quality issues and the role renewable energy can play in this important field.

ARETS continues to find that the photovoltaic systems have excellent reliability records. Likewise, the wind pumping system's have continued to show reliability improvement, to the point that many systems now rival the photovoltaic systems' 100% reliability records.

7.0 REFERENCES

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